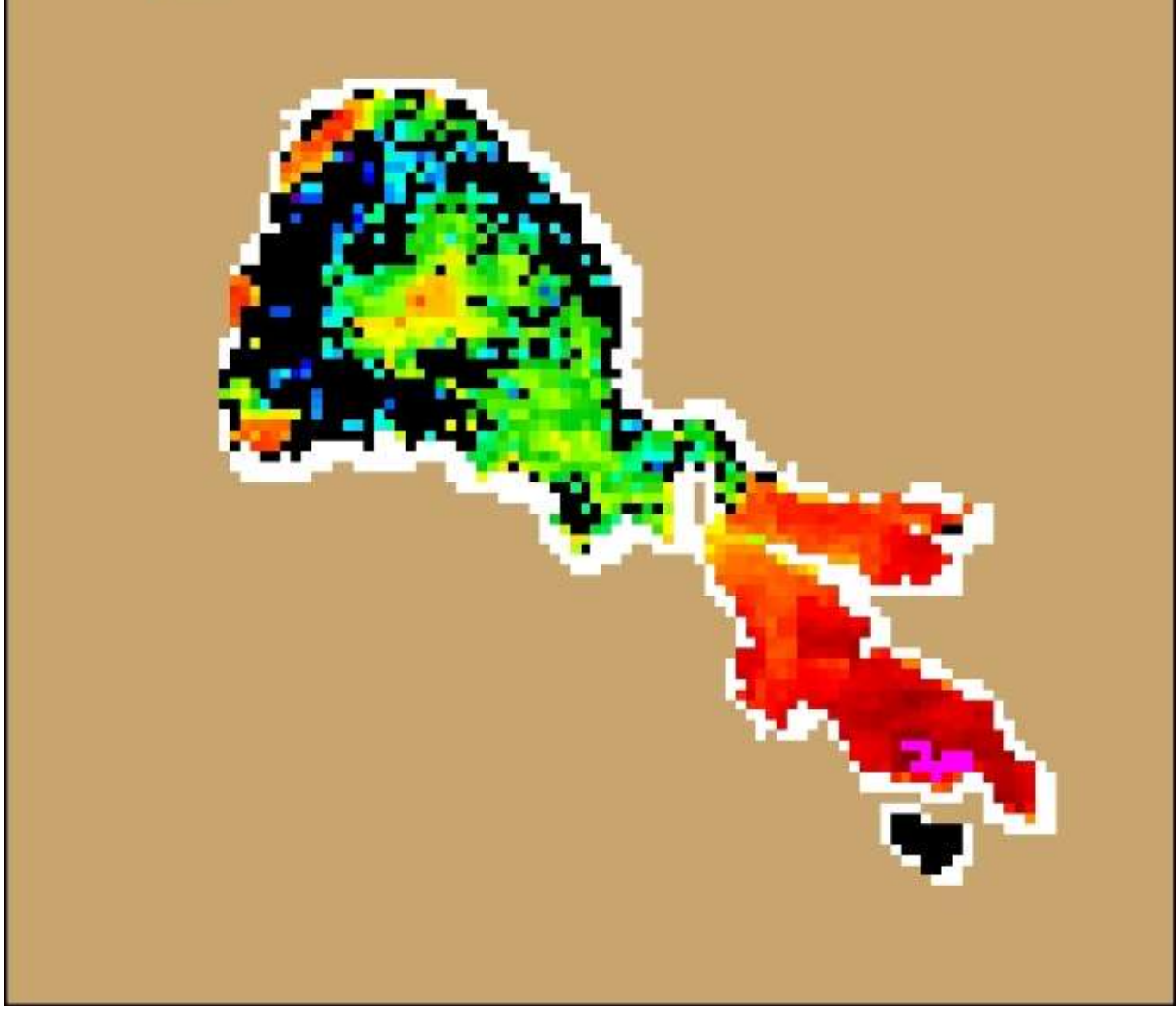
Use of Satellites to Examine Cyanobacteria in California's Large Waterbodies

Randy Turner

San Francisco Estuary Institute



SWAMP contract with SFEI

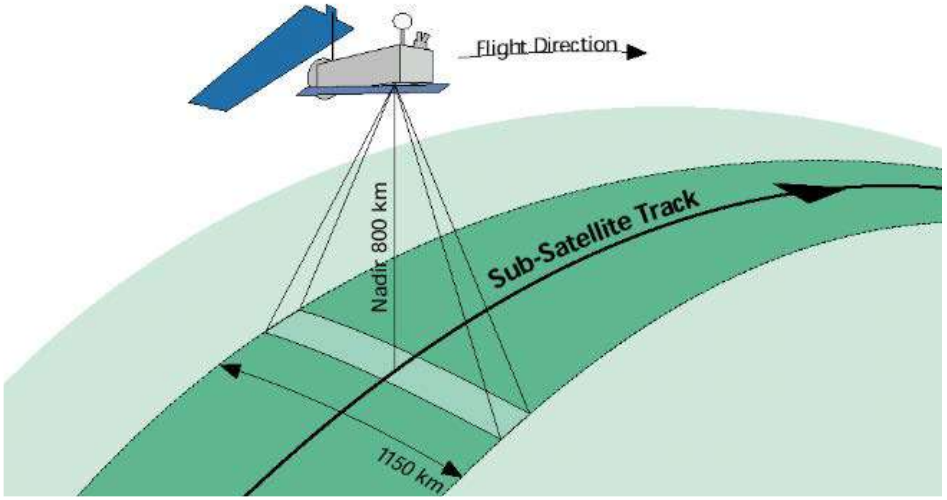
Process, analyze and report on satellite imagery provided by NOAA to protect public health from cyanobacterial Harmful Algal Blooms (cyanoHABs)

Photo credit: Jacob Kann

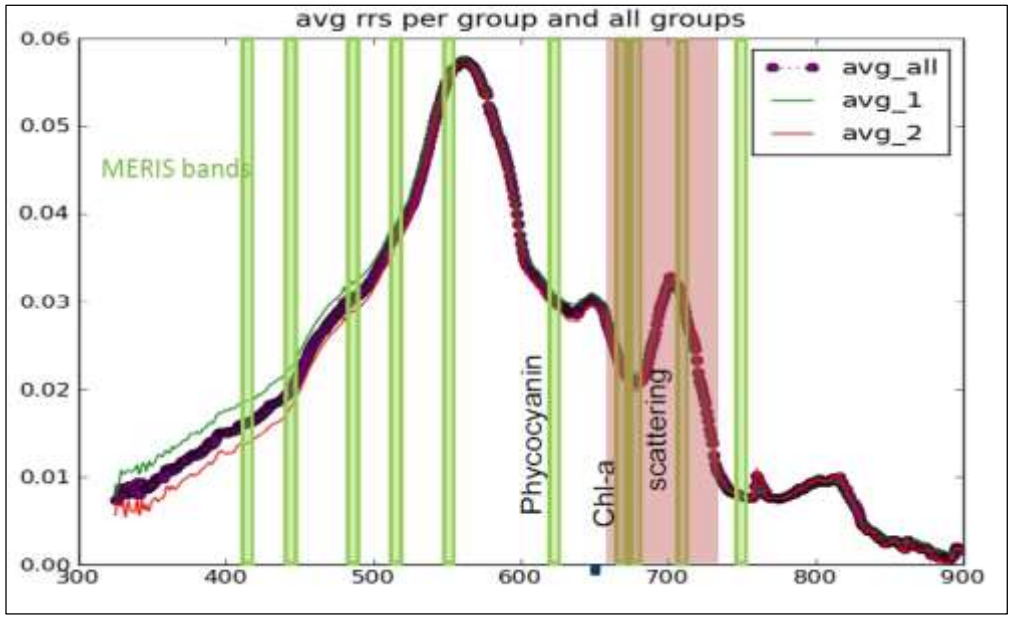
Contract with SWAMP

- Develop infrastructure for processing satellite imagery
- Historic Data
  - Analyze data from MERIS satellite (2002-2012)
  - Status and Trends report on cyanoHABs in large lakes
- New Data
  - Analyze data from OLCI on Sentinel-3 satellite (launched 2/16)
- Reporting
  - Create web portal for viewing imagery and related data
  - Inform waterbody managers when bloom conditions occur
  - Issue regular bulletins and newsletters to public

Satellite Basics

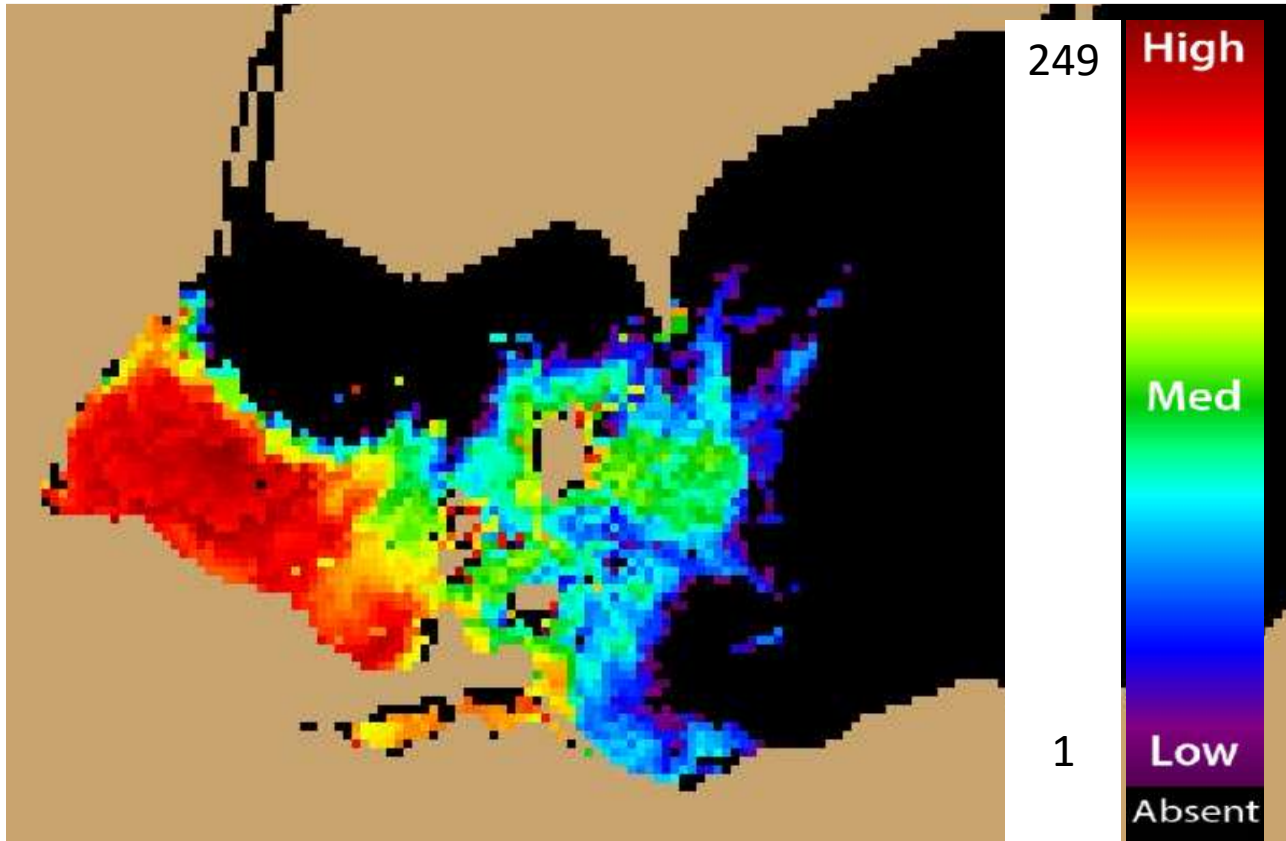


- Flyover every few days
  - Swath 1,150 km wide
  - Resolution is 300m x 300m (per pixel)
  - Satellite analyzes light absorption signature in each pixel
  - Shape in key spectral bands
  - Estimate concentration (N) for each pixel:
    - Cyanobacteria
    - Non-cyanobacteria
    - All algae



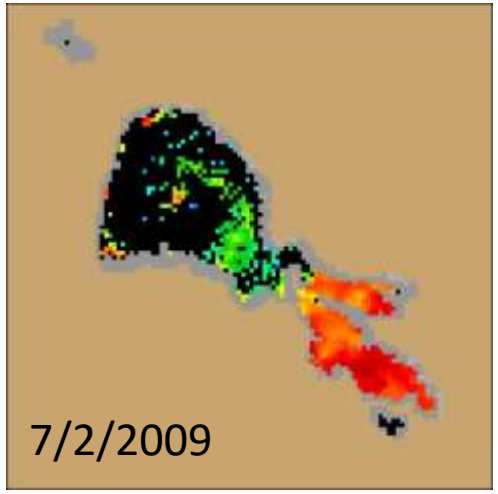
Satellite Basics

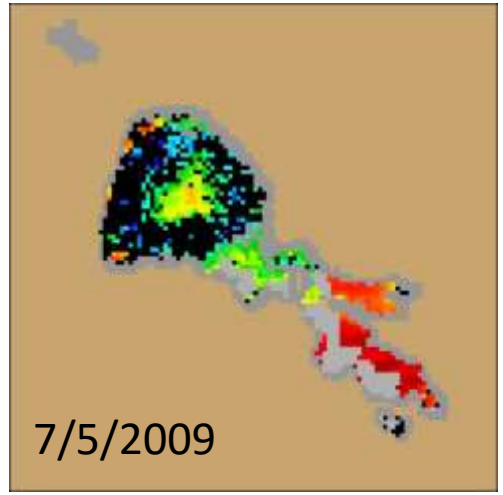
- Each pixel assigned a value of N (1-249)
- Wind, clouds, etc. impact blooms
- Generate 10 day max composite

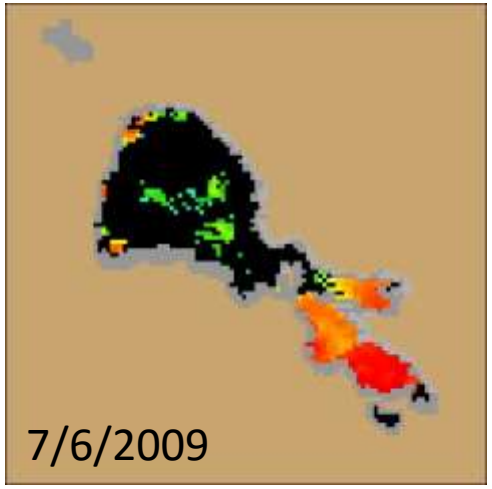


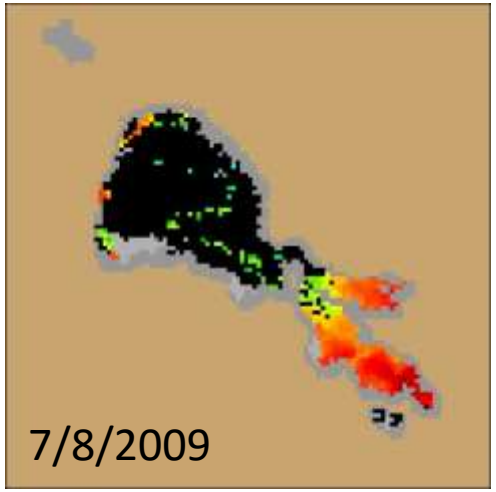
Data Processing

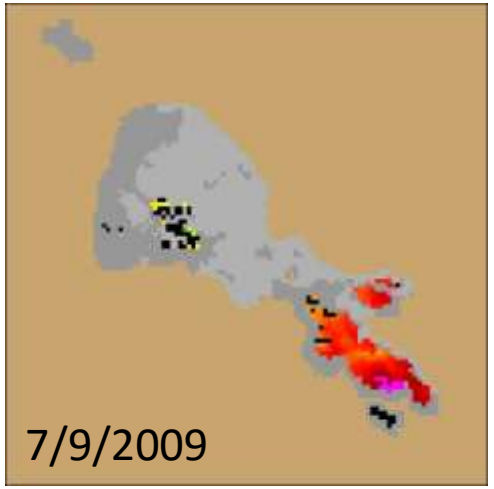
- Review all scenes for previous 10 days





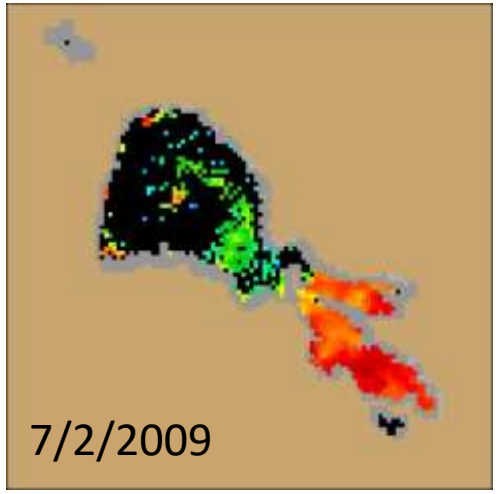


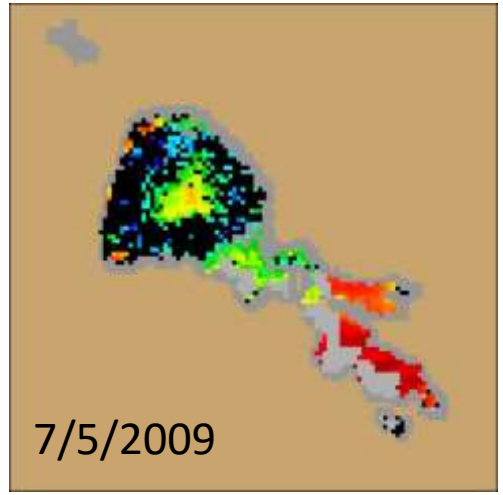


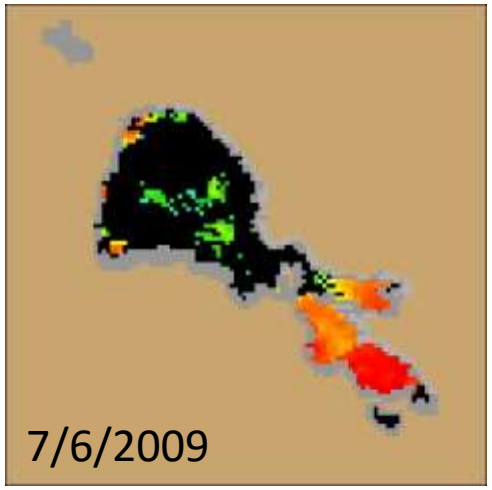


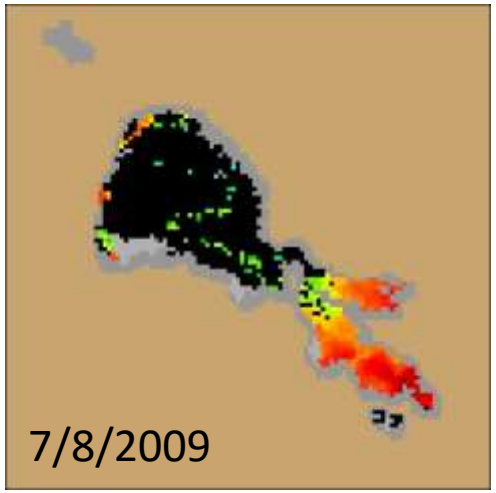
Data Processing

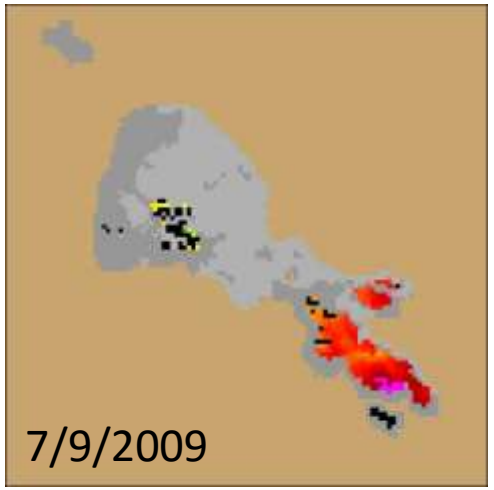
- Review all scenes for previous 10 days
- Determine maximum value for each pixel location





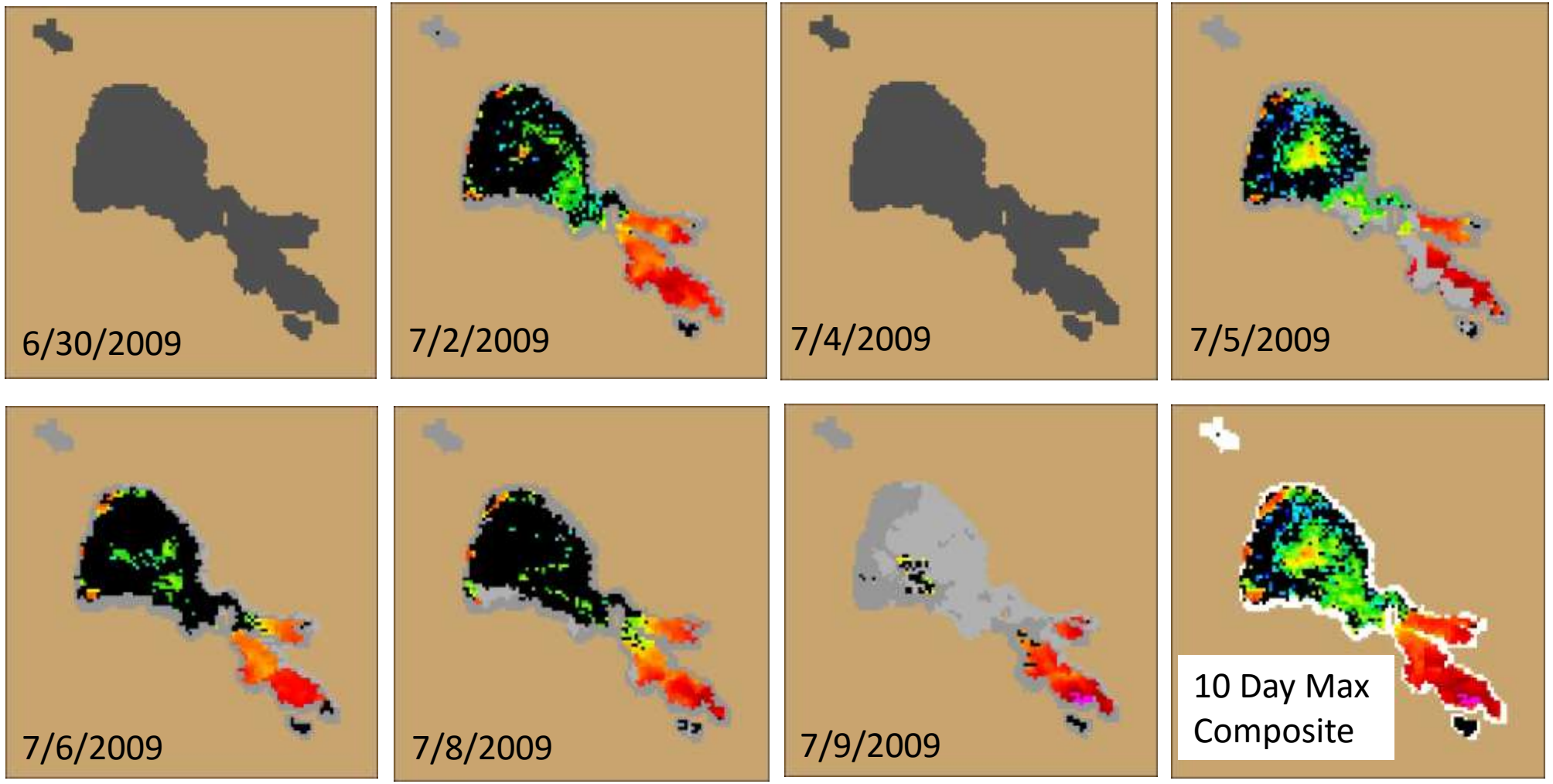






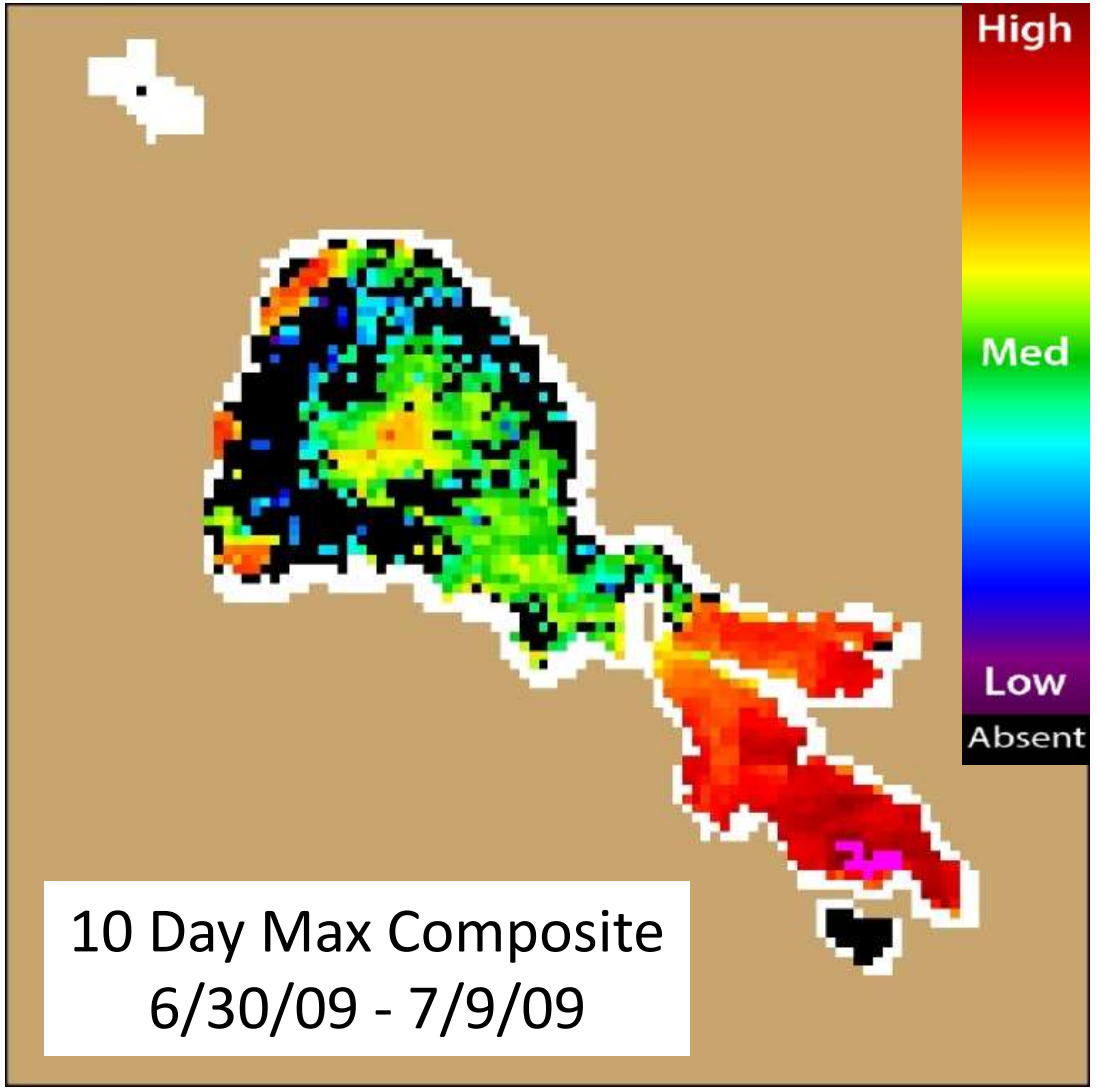
Data Processing

- Review all scenes for previous 10 days
- Determine maximum value for each pixel location
- Generate 10 day max composites



Generate Statistics

- From each 10 day max composite, generate waterbody-wide estimates for:
  - Mean
  - Median
  - 90th percentile of max
- For each ‘portion’ of bloom:
  - Cyano / Non-Cyano / Total
- Convert N to:
  - Cyanobacterial Index (CI)
  - Chlorophyll-a (ug/L)
  - Microcystis sp. (cells/mL)
- Where composites are:
  - >17 pixels (NOAA recommended)
  - >0 pixels



Generate Statistics

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- Where composites:
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  - >0 pixels

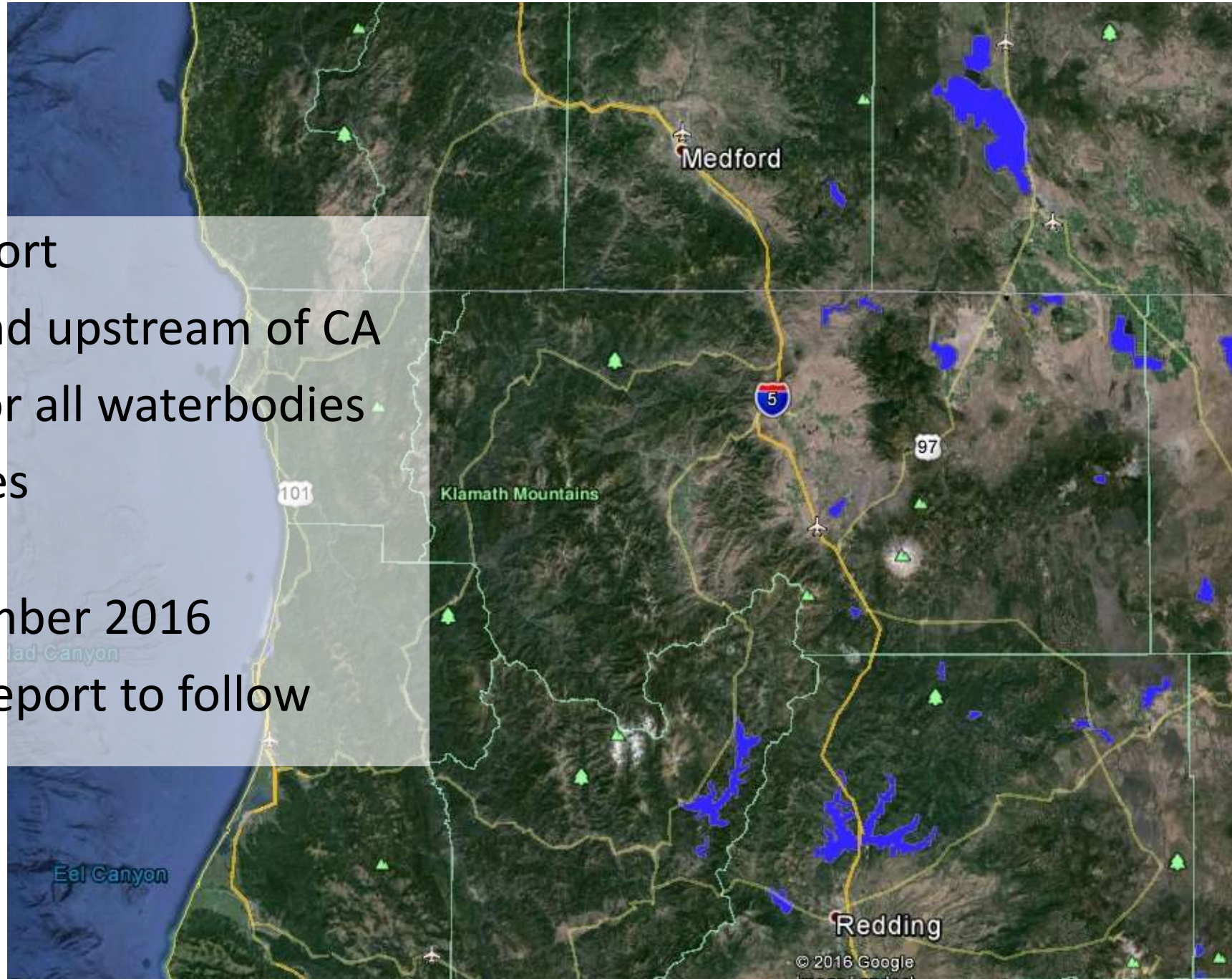
			Cyano Mean >17	Cyano Median >17	Cyano 90th % >17
start_date	end_date	Pixels	MC (cells/mL)	MC (cells/mL)	MC (cells/mL)
6/22/2009	7/1/2009	1757	109,648	131,826	1,995,262
6/23/2009	7/2/2009	1779	123,027	154,882	1,949,845
6/24/2009	7/3/2009	1739	109,648	134,896	1,949,845
6/25/2009	7/4/2009	1739	109,648	134,896	1,949,845
6/26/2009	7/5/2009	1721	134,896	181,970	1,778,279
6/27/2009	7/6/2009	1709	125,893	186,209	1,548,817
6/28/2009	7/7/2009	1709	125,893	186,209	1,548,817
6/29/2009	7/8/2009	1733	134,896	194,984	1,584,893
6/30/2009	7/9/2009	1721	125,893	186,209	1,621,810

10 Day Max Composite
6/30/09 - 7/9/09

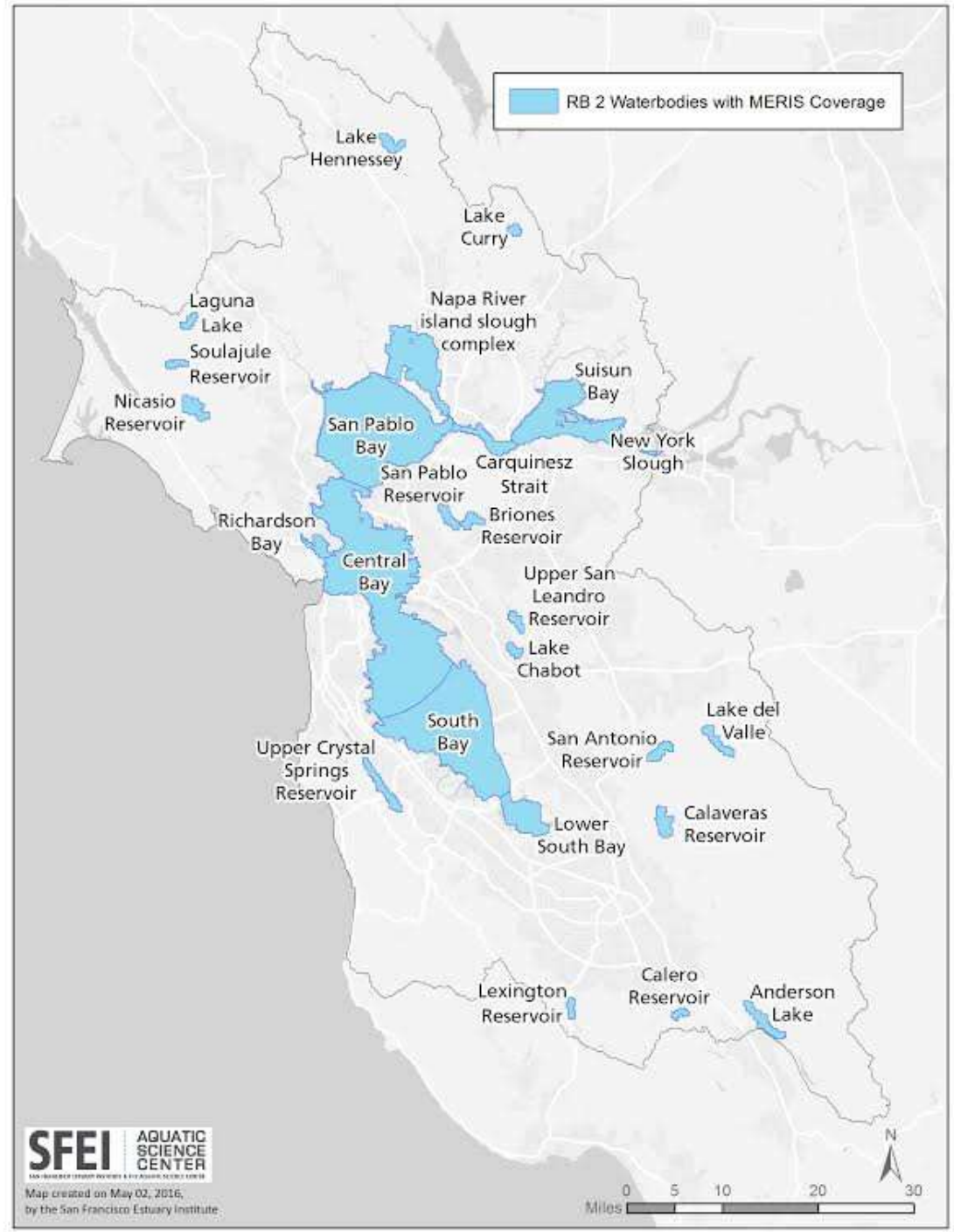
Generate 81 columns of data for each day for each waterbody!

Historic Data

- Status and Trends report
- 255 waterbodies in and upstream of CA
- Summarize findings for all waterbodies
- Select ~20 waterbodies
  - Detailed analysis
- Final report by September 2016
- More extensive S&T report to follow



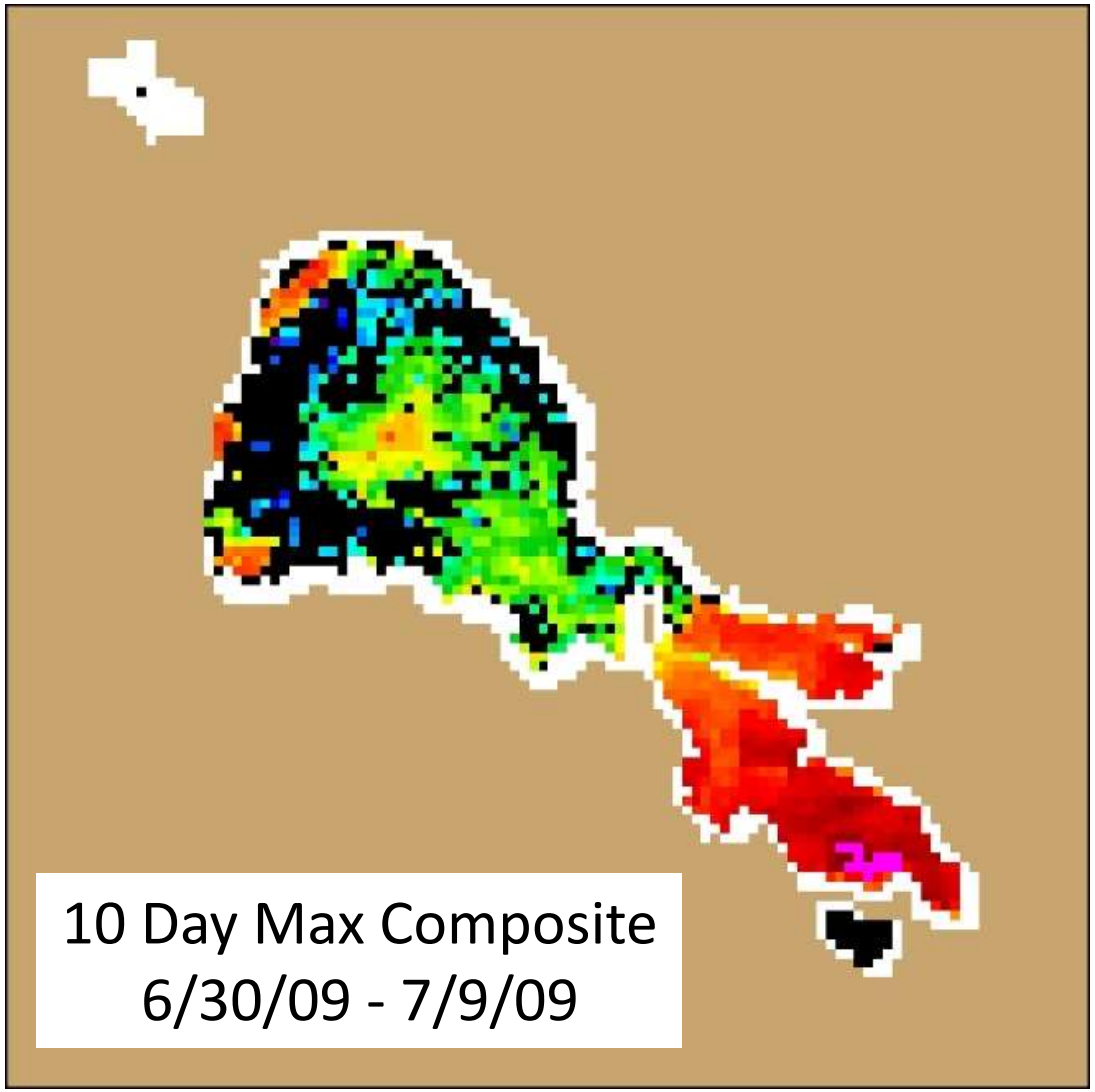
Waterbodies in RB2 with MERIS Coverage



Future Data

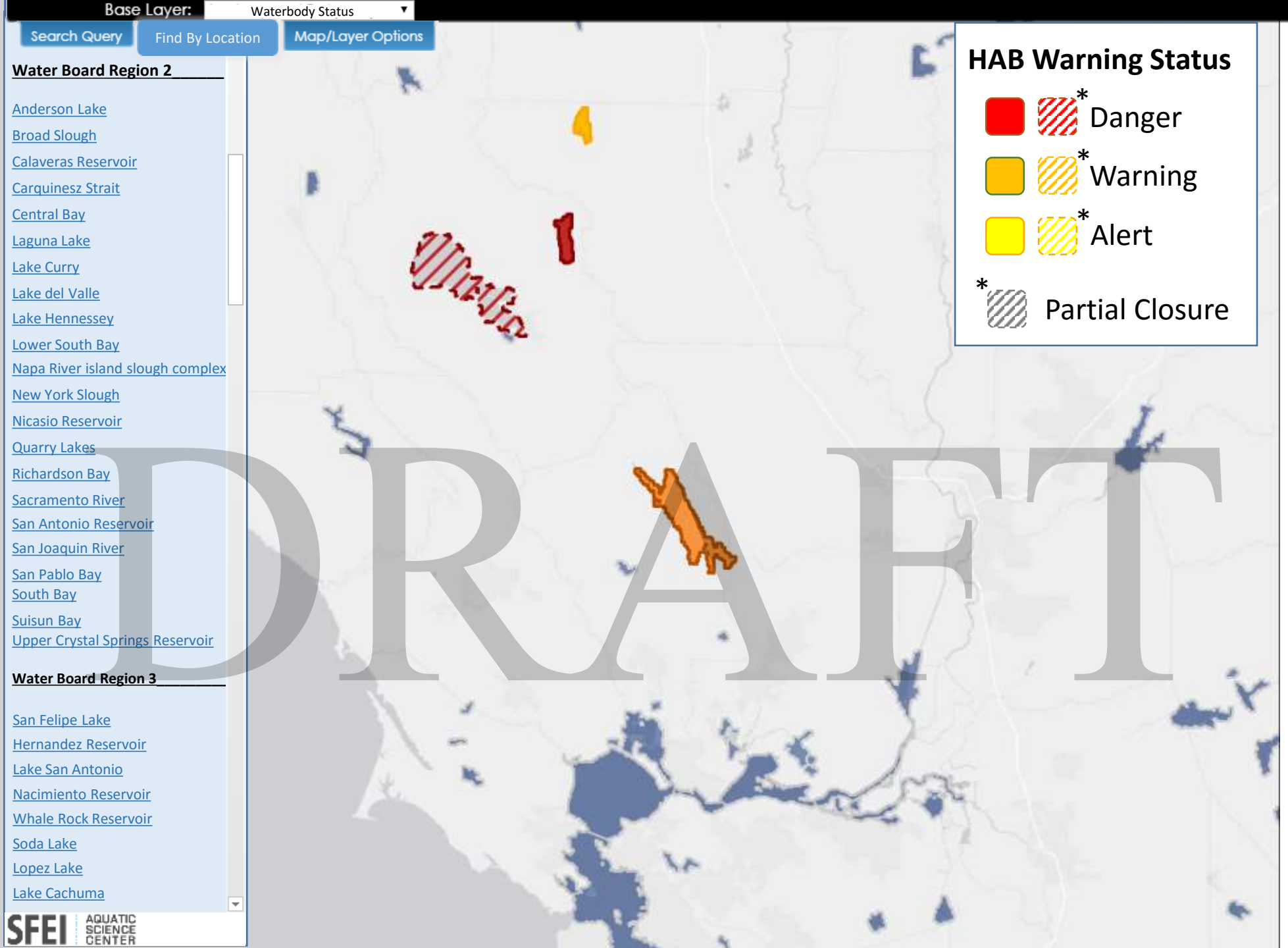
- OLCI/Sentinel-3 satellite
- Download and analyze new data regularly
- Communicate data to guide event response monitoring by:
  - Waterbody managers
  - County public health officials
  - Regional Board/SWAMP
- Publish:
  - Bi-weekly bulletins
  - Quarterly newsletter
  - Web maps and data

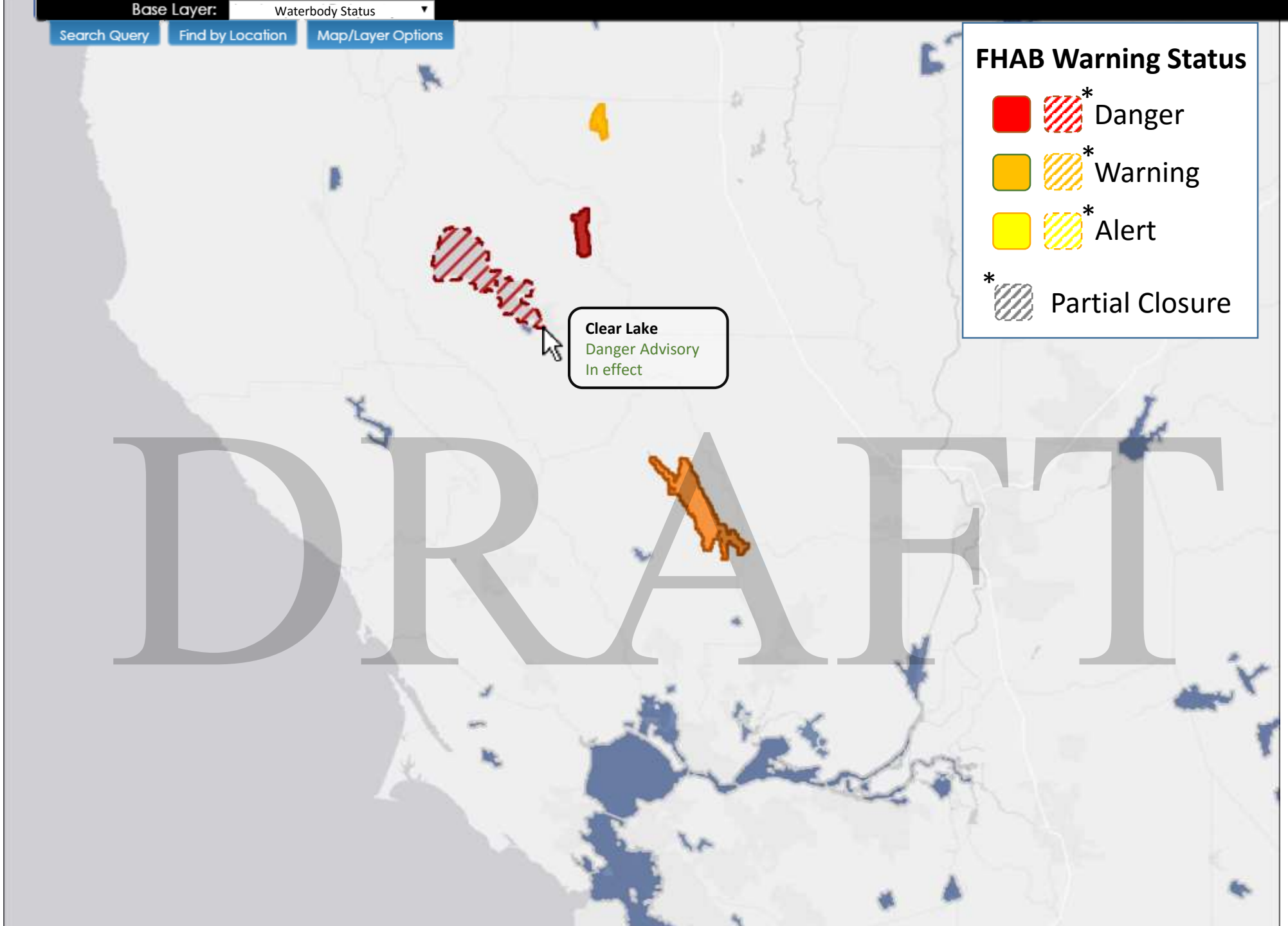
Need contact information



Interactive Maps for MyWaterQuality Portal

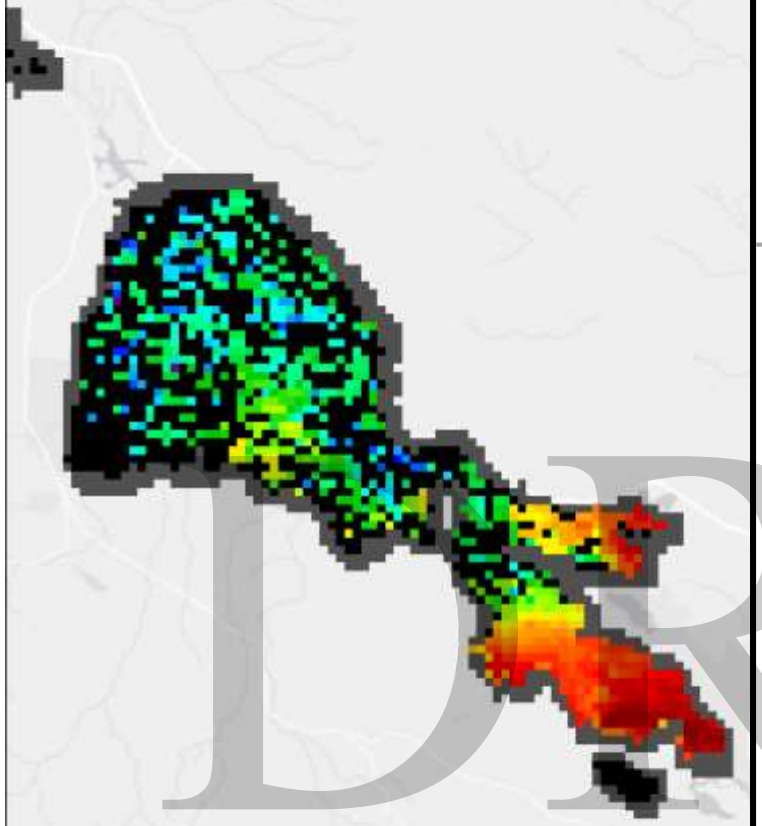
- DRAFT mock-ups of what interactive maps may look like
- Posted Waterbody map
- Satellite Data map


Base Layer:
Waterbody Status
Search Query
Find By Location
Map/Layer Options
Water Board Region 2
Anderson Lake
Broad Slough
Calaveras Reservoir
Carquinesz Strait
Central Bay
Laguna Lake
Lake Curry
Lake del Valle
Lake Hennessey
Lower South Bay
Napa River island slough complex
New York Slough
Nicasio Reservoir
Quarry Lakes
Richardson Bay
Sacramento River
San Antonio Reservoir
San Joaquin River
San Pablo Bay
South Bay
Suisun Bay
Upper Crystal Springs Reservoir
Water Board Region 3
San Felipe Lake
Hernandez Reservoir
Lake San Antonio
Nacimiento Reservoir
Whale Rock Reservoir
Soda Lake
Lopez Lake
Lake Cachuma
SFEI
AQUATIC SCIENCE CENTER
HAB Warning Status
Danger
Warning
Alert
Partial Closure
DRAFT


Base Layer:
Waterbody Status
Search Query
Find by Location
Map/Layer Options
FHAB Warning Status
Danger
Warning
Alert
Partial Closure
Clear Lake
Danger Advisory
In effect
DRAFT

Base Layer: 10 Day Biomass estimate

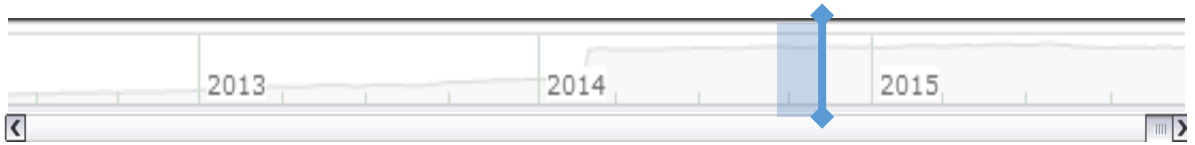
Search Query | Find by Location | Map/Layer Options



MERIS 10-Day Composite Biomass Estimate
May 20, 2014 – May 30, 2014

Clear Lake, Lake County, CA

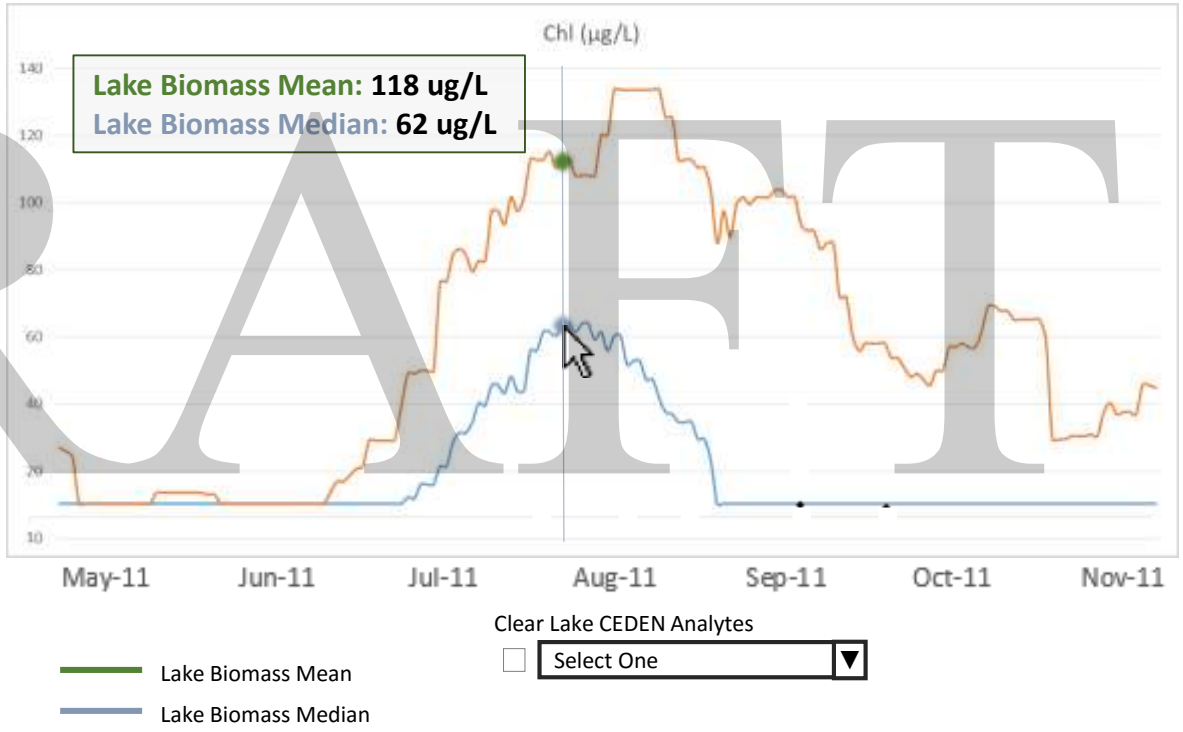
Current Advisory: State and county agencies are urging swimmers, boaters and recreational users to avoid contact with blue-green algae now blooming in Clear Lake located in Lake County, CA. The lake has been posted with advisories warning of any contact with the water because of possible toxins associated with the algae. (Read More)



Display Last 10 Days

Trends | Water Quality | Data Table

Cyanobacteria Estimated Biomass & Toxicity

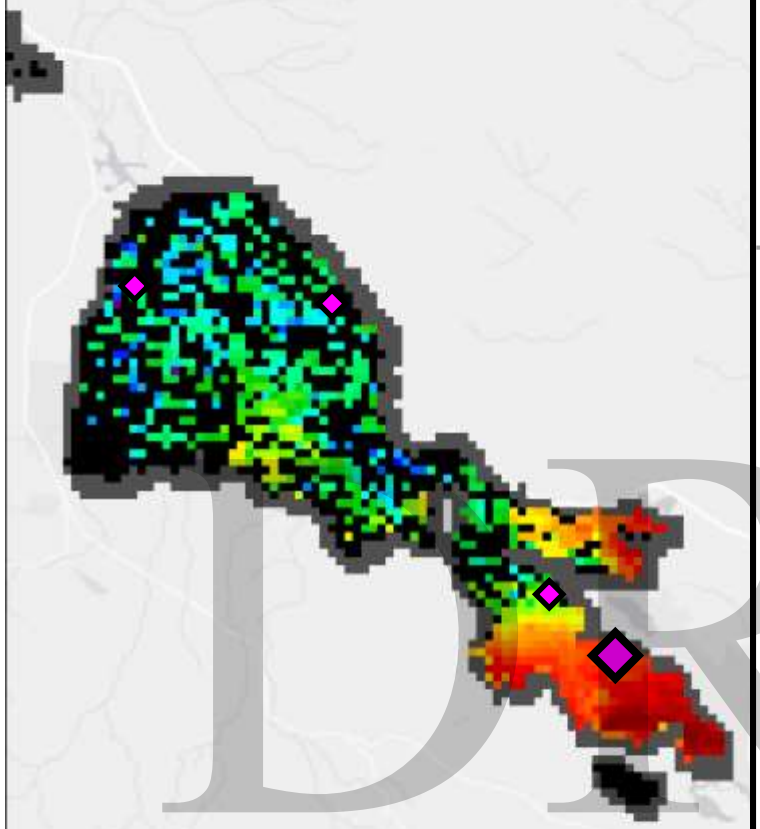


Clear Lake CEDEN Analytes

Select One

Base Layer: 10 Day Biomass estimate

Search Query | Find by Location | Map/Layer Options



CEDEN Sample Location

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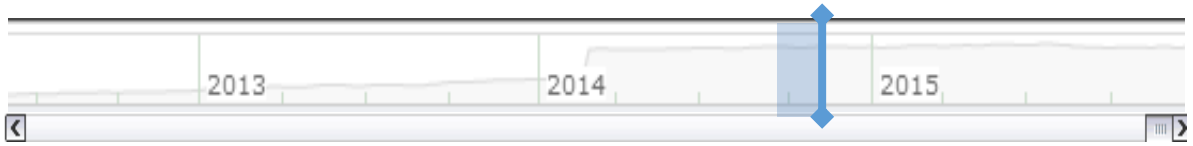
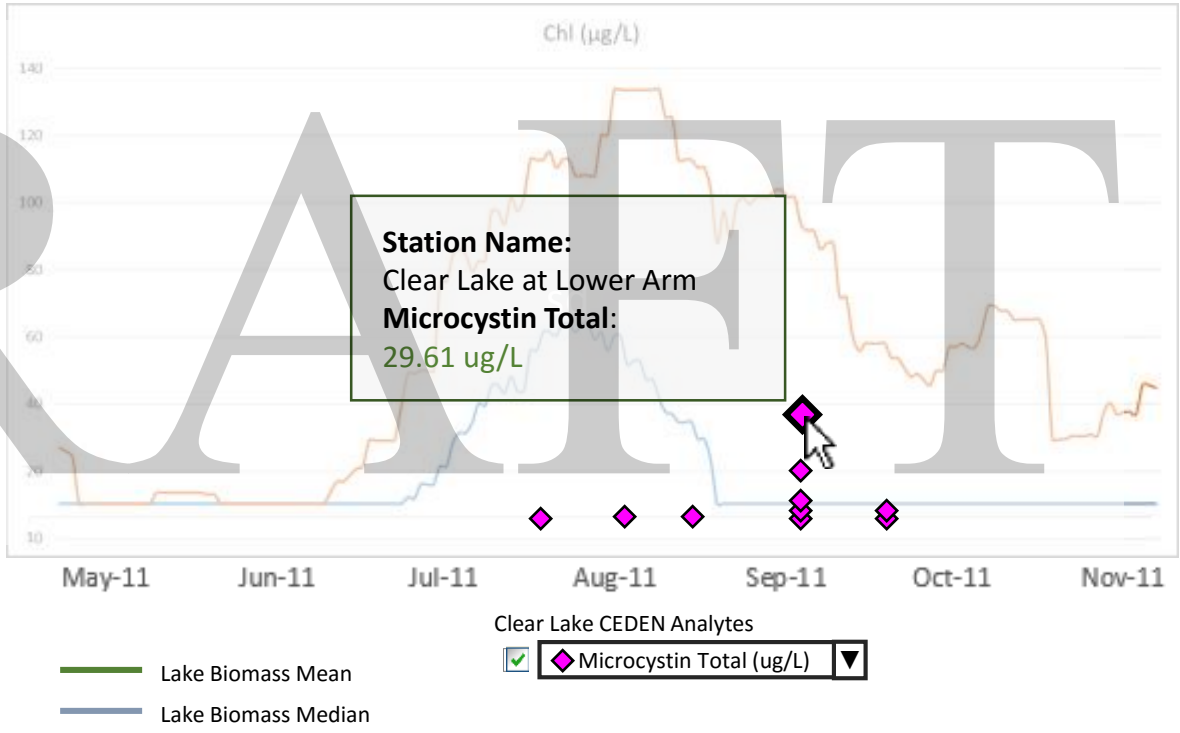
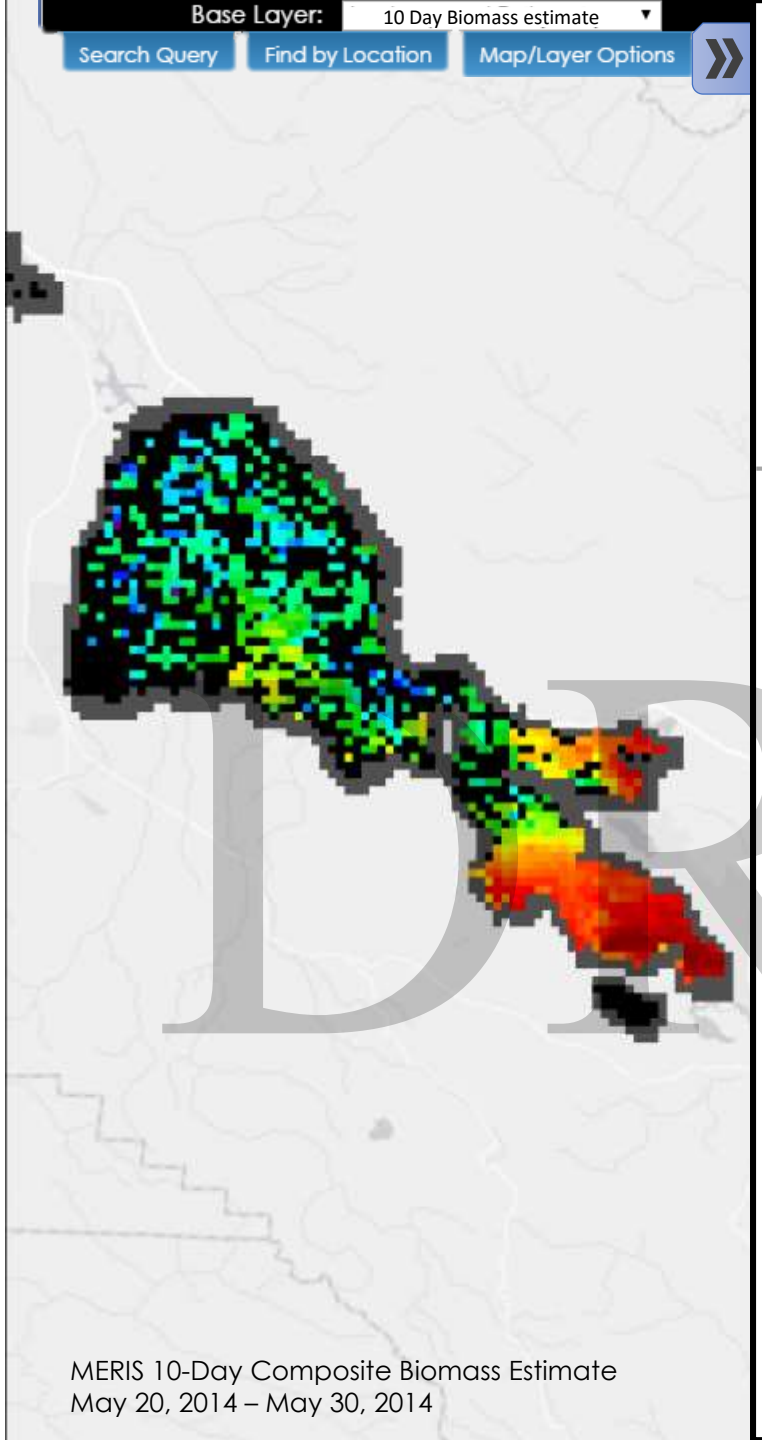


Display Last 10 Days

Trends | Water Quality | Data Table

Cyanobacteria Estimated Biomass & Toxicity





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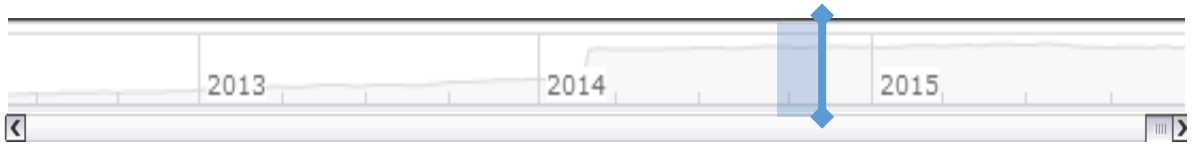


Trends | Water Quality | **Data Table**

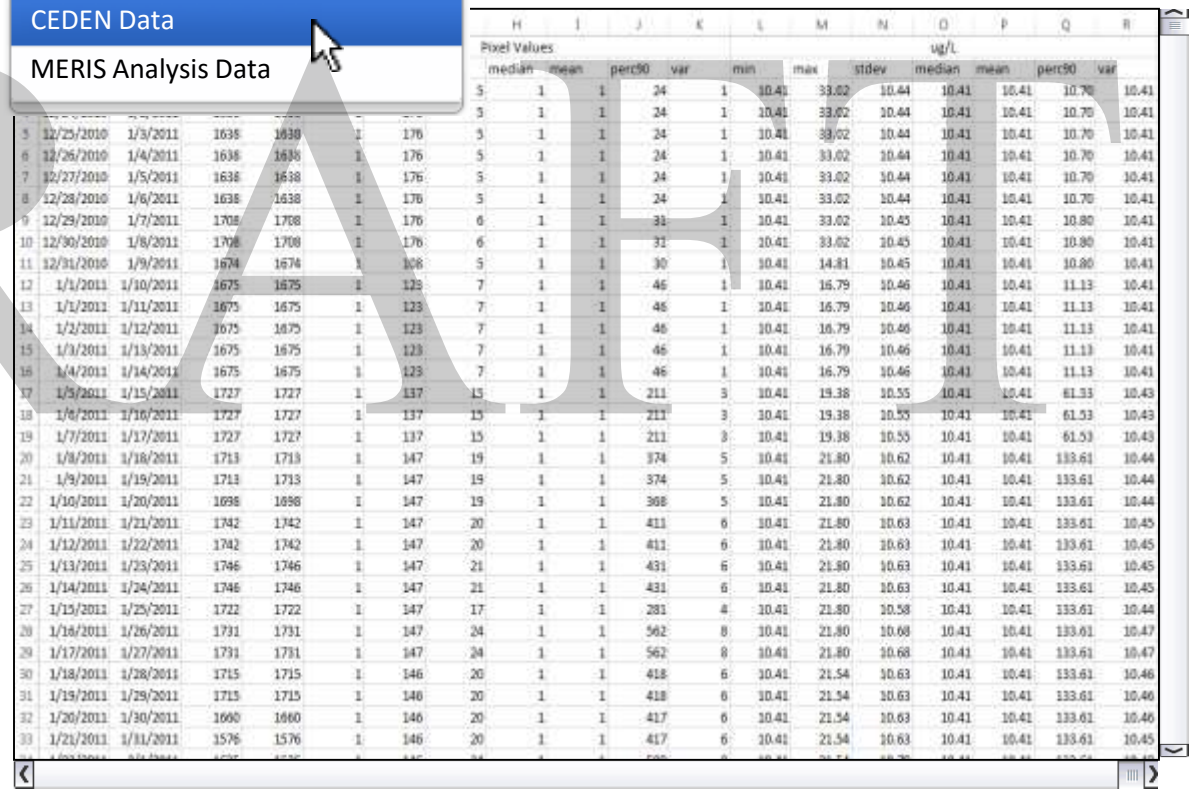
Select Data for Waterbody

CEDEN Data

MERIS Analysis Data

From Jan 8, 2016 To Feb 8, 2016

Download Table



Early Review of Historic Satellite Data for Calaveras Reservoir

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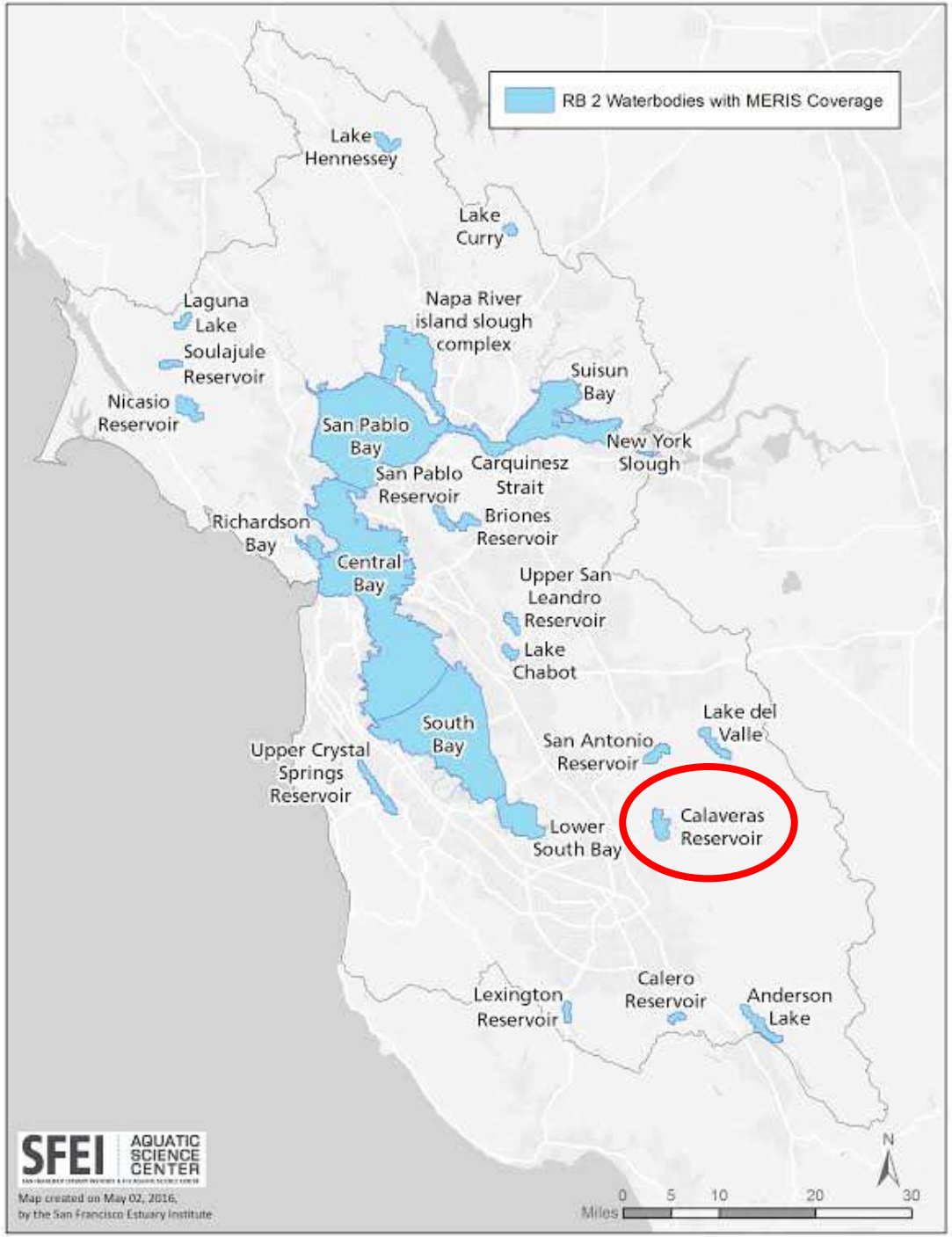
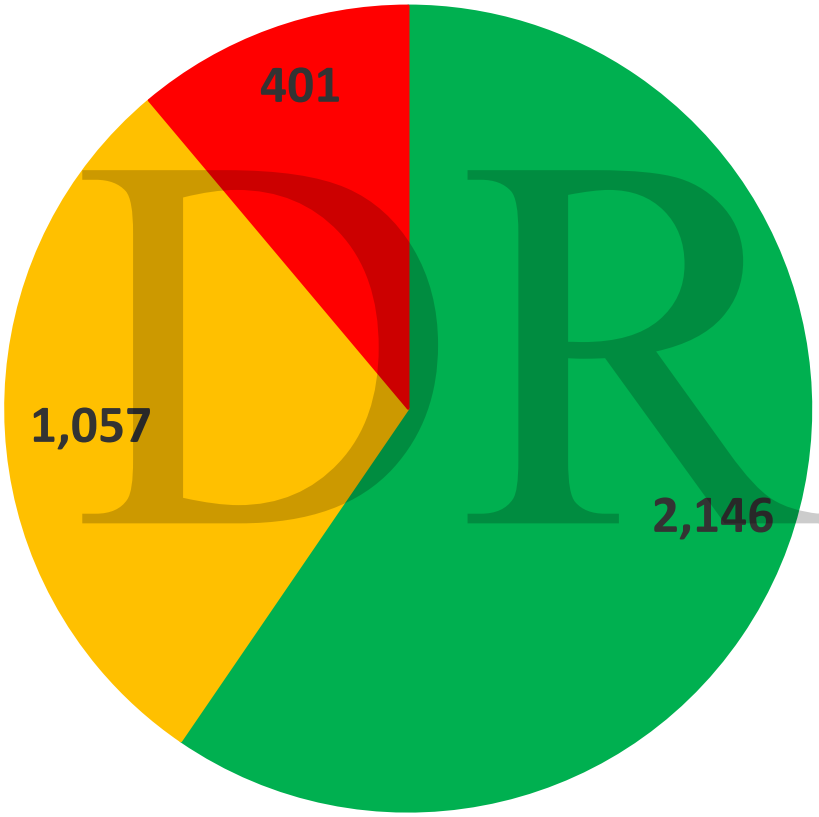
All data preliminary
Please do not cite

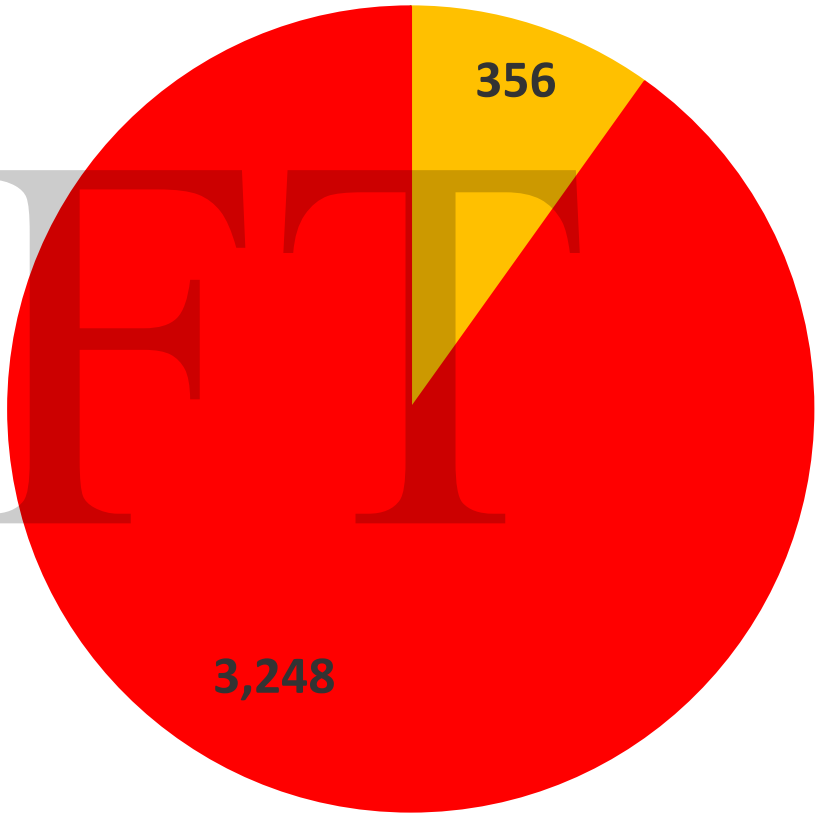


Daily Pixel Counts
>18 pixels=Green, 1 to 17 pixels=Yellow, No Data=Red

Calaveras Reservoir



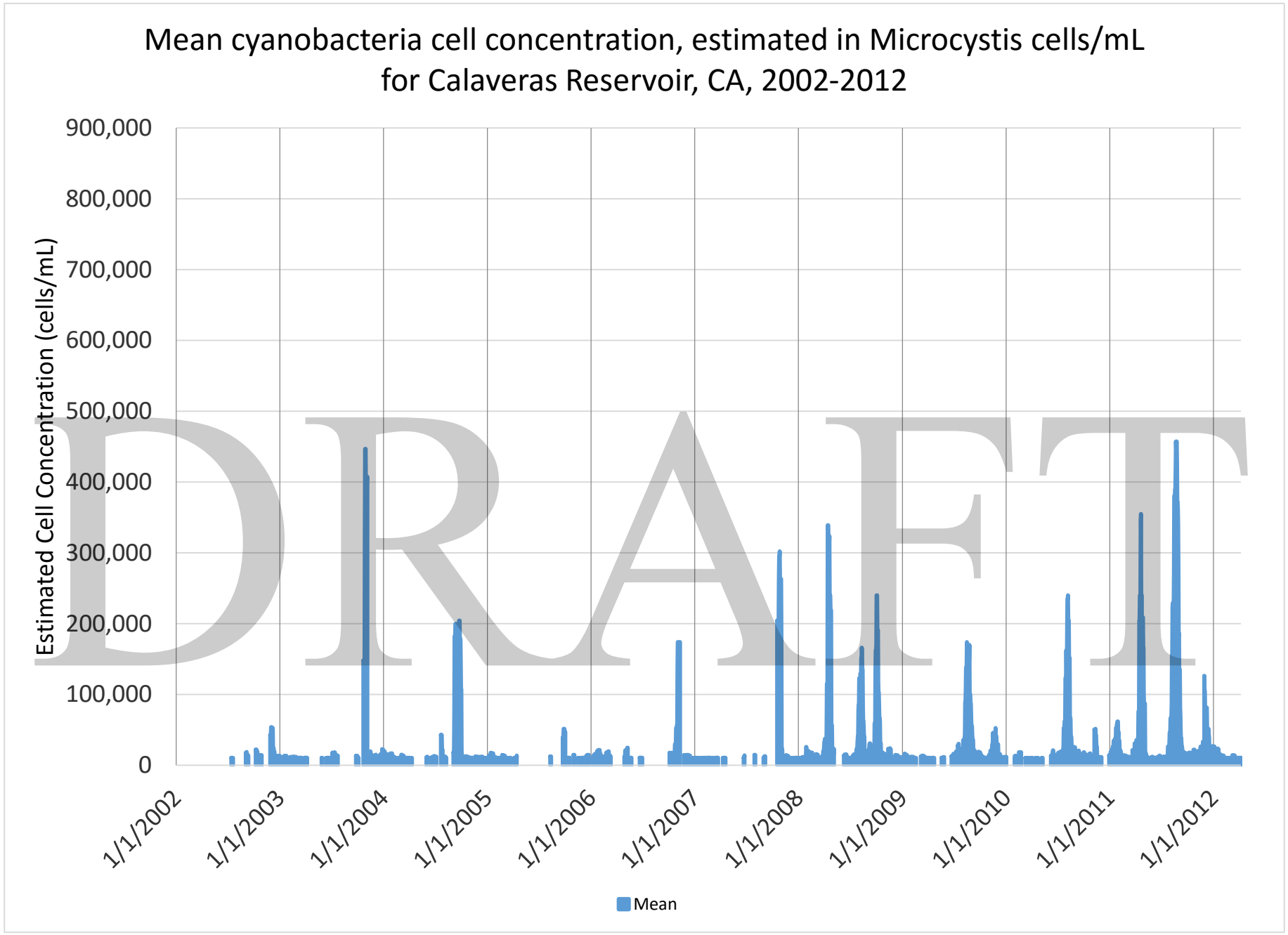
Lake Chabot

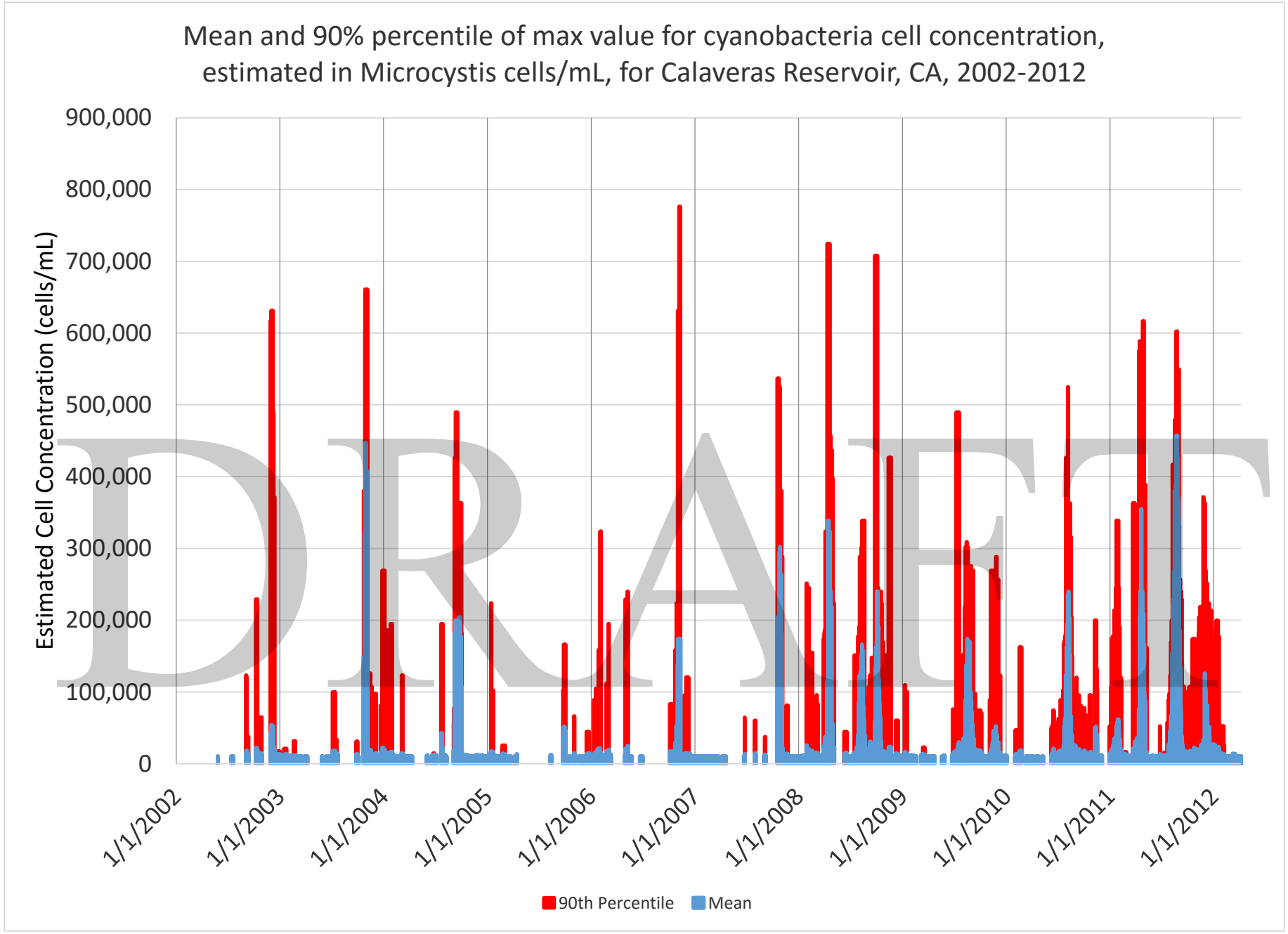


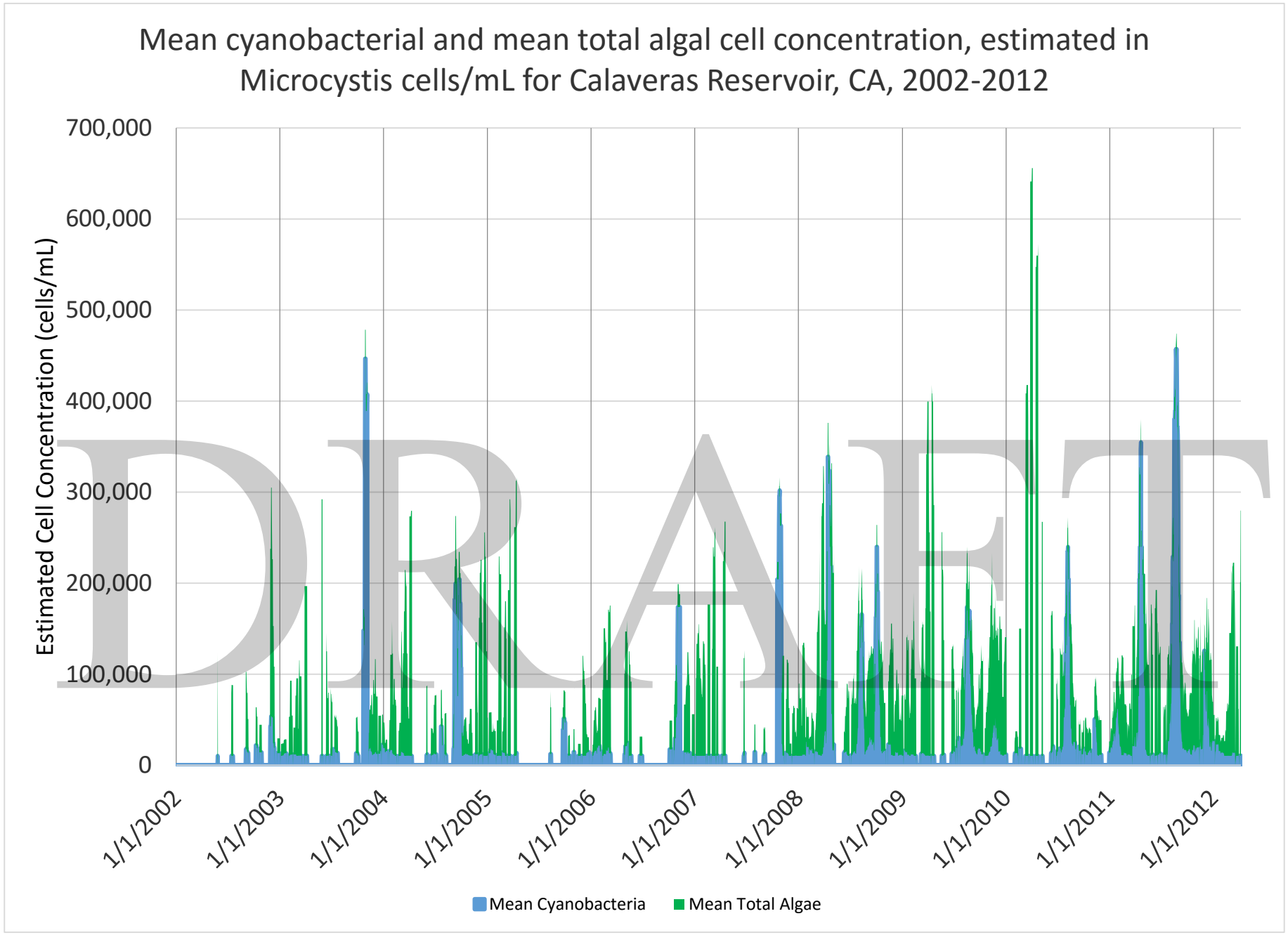
New CA Thresholds for HABs

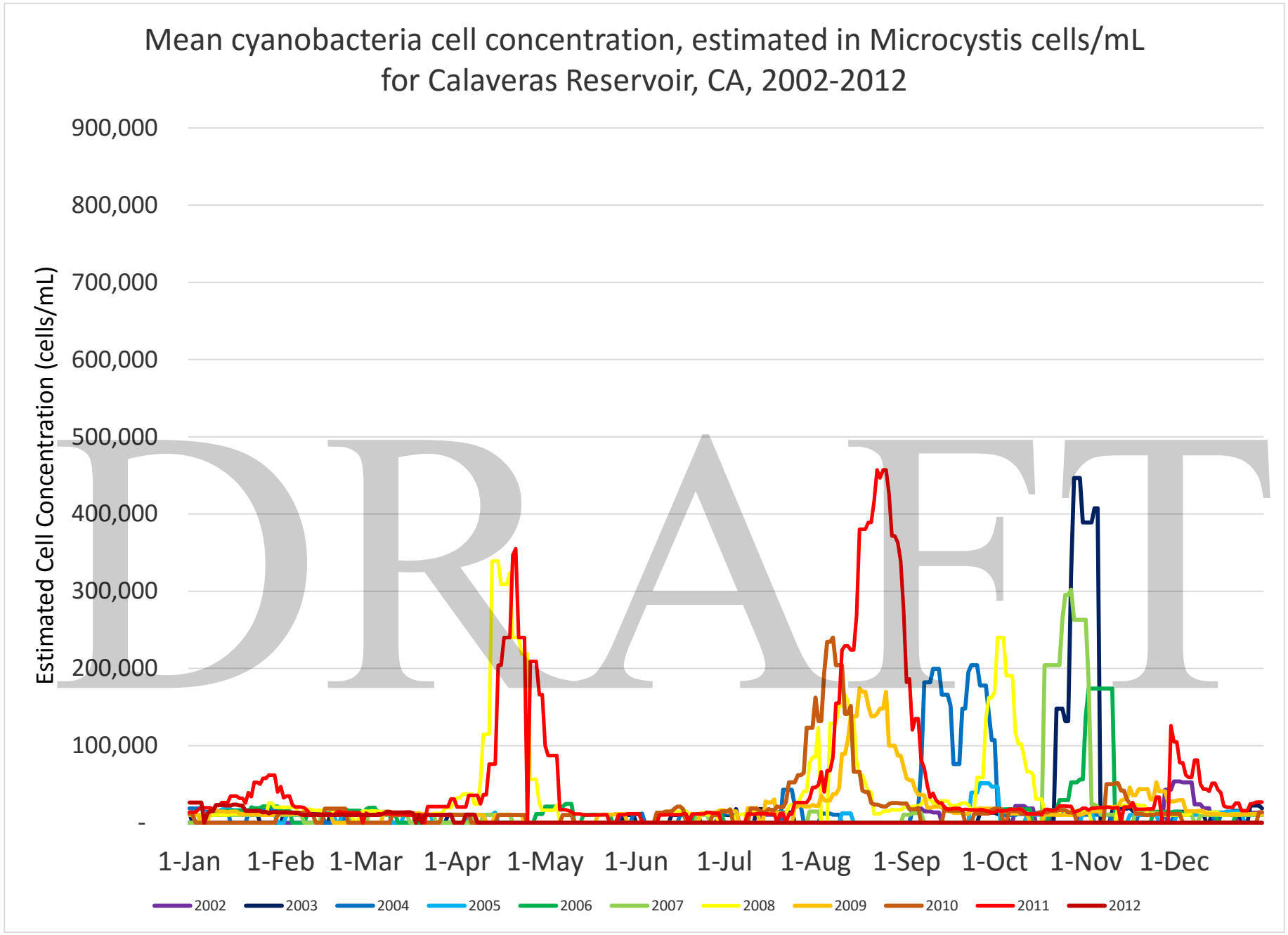
- Thresholds mostly toxin related
- Cell density of **4,000 cells/mL** only for lowest 'Action Level'
- Background levels for satellite data **10,000 cells/mL**

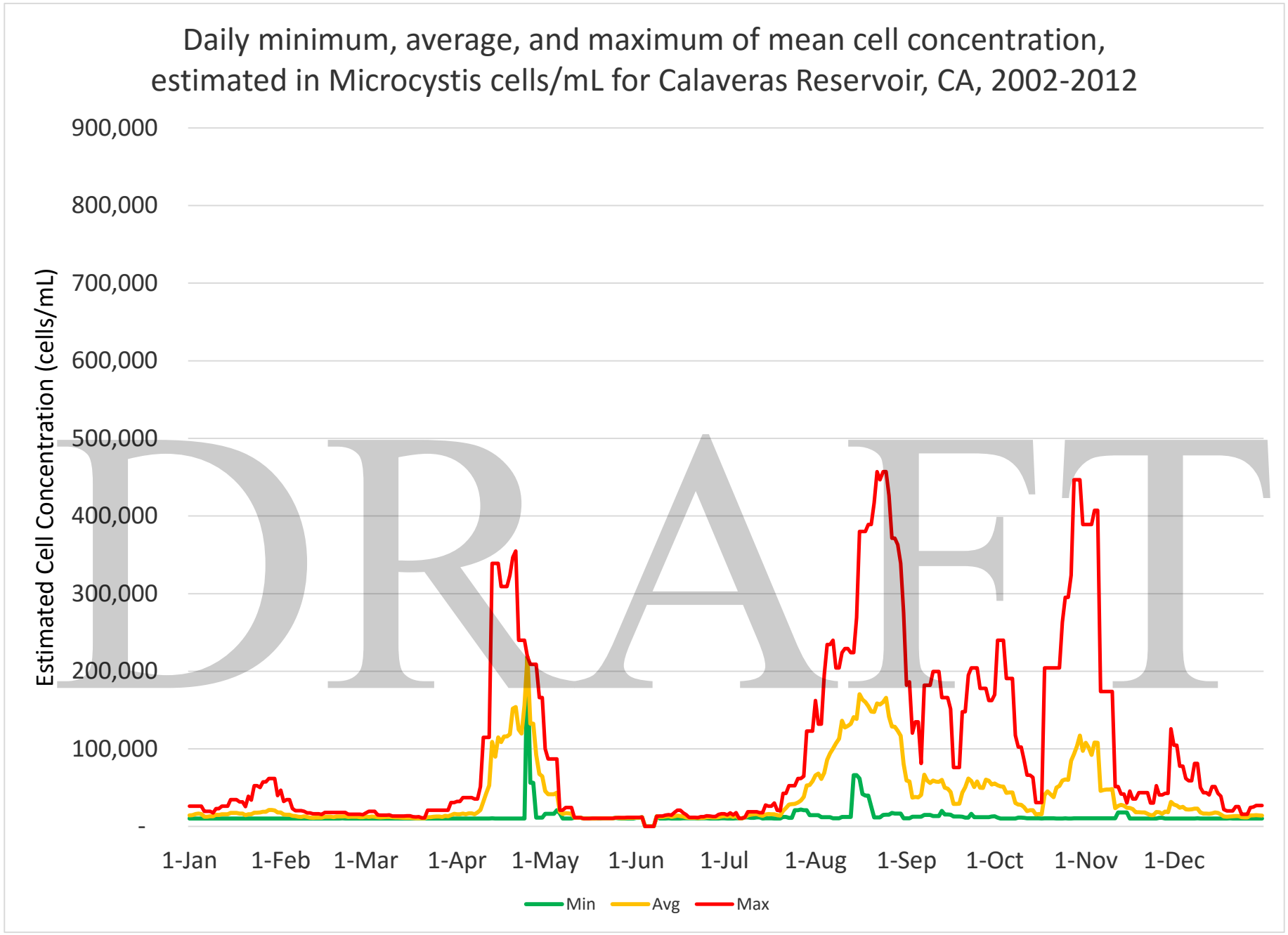
	Action Trigger	Warning TIER 1	Danger TIER 2
Primary Thresholds [a]			
Total Microcystins [b]	**0.8** µg/L	**6** µg/L	**20** µg/L
Anatoxin-a	**Detection** [c]	**20** µg/L	**90** µg/L
Cylindrospermopsin	**1** µg/L	**4** µg/L	**12** µg/L
Secondary Thresholds			
Cell Density (*Toxin producing cells*)	**4,000** cells/mL	--	--
Site Specific Indicators of Cyanobacteria	Blooms, scums, mats	--	--

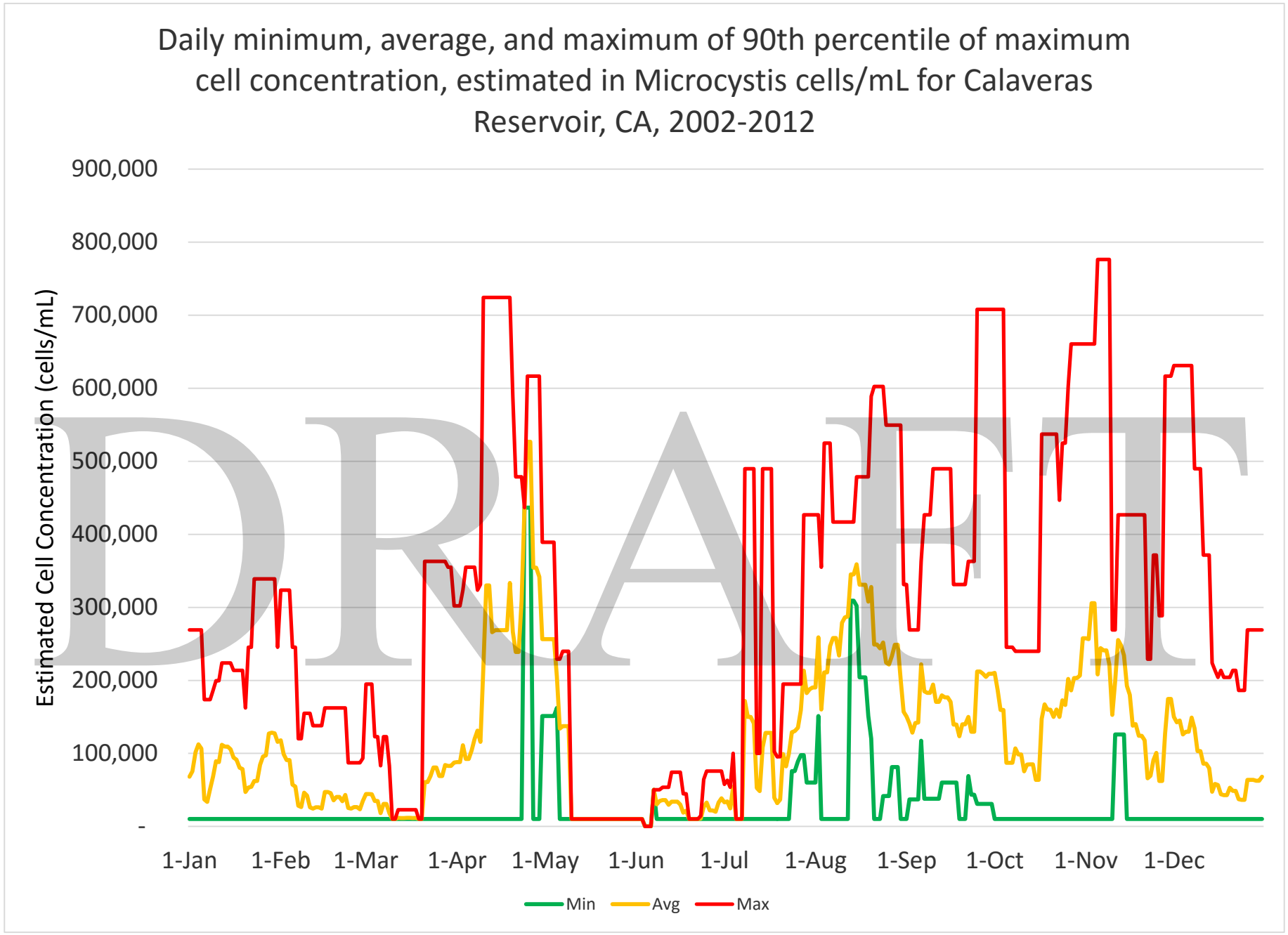

Mean cyanobacteria cell concentration, estimated in Microcystis cells/mL
for Calaveras Reservoir, CA, 2002-2012
Estimated Cell Concentration (cells/mL)
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/2002
1/1/2003
1/1/2004
1/1/2005
1/1/2006
1/1/2007
1/1/2008
1/1/2009
1/1/2010
1/1/2011
1/1/2012
Mean
DRAFT


Mean and 90% percentile of max value for cyanobacteria cell concentration, estimated in Microcystis cells/mL, for Calaveras Reservoir, CA, 2002-2012
Estimated Cell Concentration (cells/mL)
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/2002
1/1/2003
1/1/2004
1/1/2005
1/1/2006
1/1/2007
1/1/2008
1/1/2009
1/1/2010
1/1/2011
1/1/2012
90th Percentile
Mean
DRAFT


Mean cyanobacterial and mean total algal cell concentration, estimated in Microcystis cells/mL for Calaveras Reservoir, CA, 2002-2012
Estimated Cell Concentration (cells/mL)
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/2002
1/1/2003
1/1/2004
1/1/2005
1/1/2006
1/1/2007
1/1/2008
1/1/2009
1/1/2010
1/1/2011
1/1/2012
Mean Cyanobacteria
Mean Total Algae
DRAFT

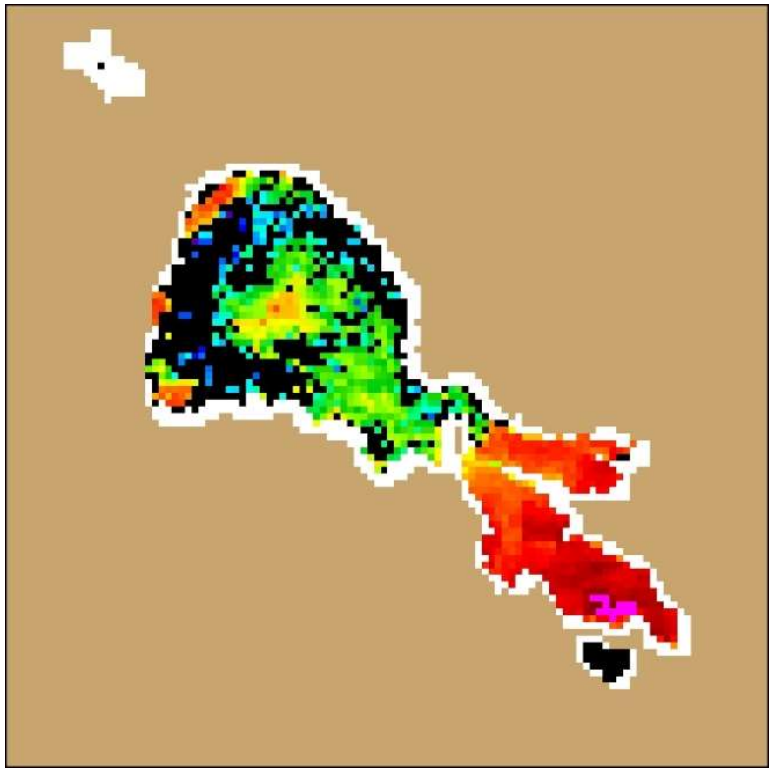

Mean cyanobacteria cell concentration, estimated in Microcystis cells/mL
for Calaveras Reservoir, CA, 2002-2012
Estimated Cell Concentration (cells/mL)
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
-
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
1-Oct
1-Nov
1-Dec
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012


Daily minimum, average, and maximum of mean cell concentration, estimated in Microcystis cells/mL for Calaveras Reservoir, CA, 2002-2012
Estimated Cell Concentration (cells/mL)
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
-
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
1-Oct
1-Nov
1-Dec
Min
Avg
Max
DRAFT

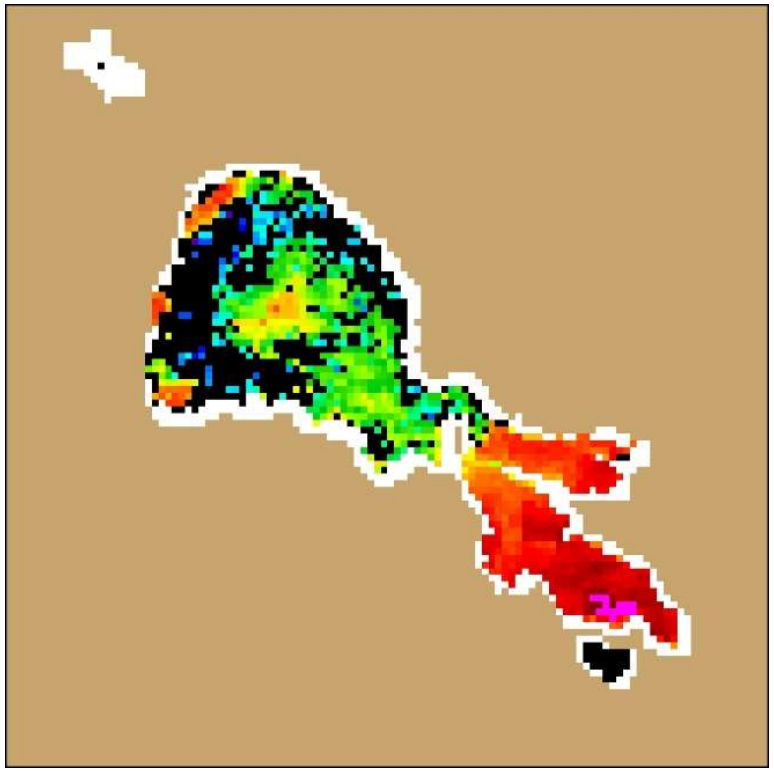

Daily minimum, average, and maximum of 90th percentile of maximum cell concentration, estimated in Microcystis cells/mL for Calaveras Reservoir, CA, 2002-2012
Estimated Cell Concentration (cells/mL)
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
-
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
1-Oct
1-Nov
1-Dec
Min
Avg
Max
DRAFT

Satellites- What They Can't Do

- Cyano blooms can be detected…but…
  - Clouds block images
  - Less confidence with lowest algal densities
  - False positives can occur
  - All cyanobacteria (including non-toxin producers)
  - Doesn't measure toxin levels
  - Screening tool- No direct comparisons to HAB thresholds
  - Limited to large lakes (currently)



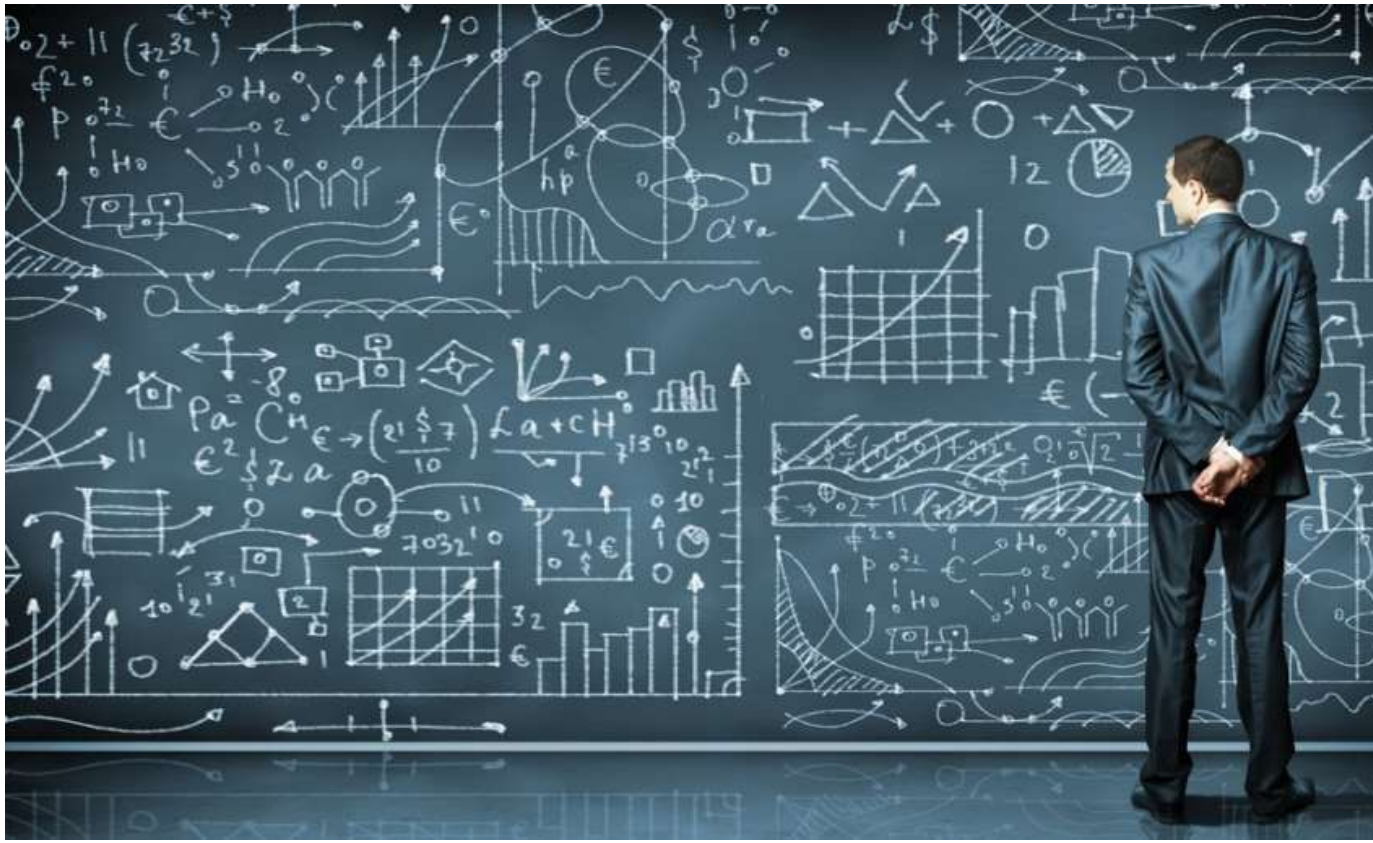
Satellites- What They Can Do



- Cyano blooms can be detected and…
  - Historic- Provide understanding of bloom conditions during 2002-2012
    - Identify trends and severity of blooms
  - Future- Provide bloom status and location in near-real time
    - Inform waterbody managers of bloom conditions from initiation through senescence
    - Better target event response monitoring to protect public health
  - Complement data collected by water managers
  - Hundreds of waterbodies in CA monitored at once

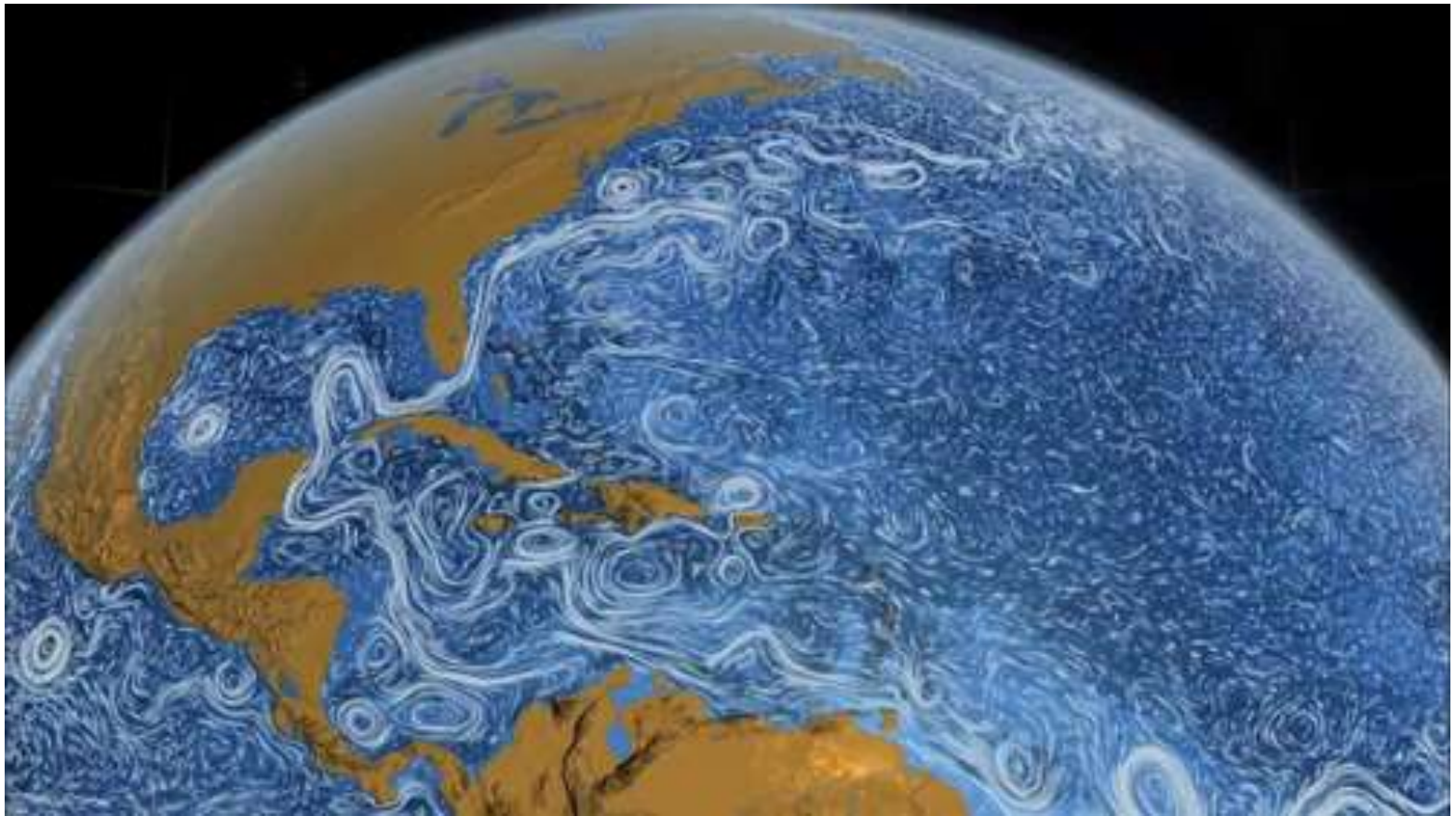
Further Research Needed

- Satellite data will be available to public
- Compare to:
  - Water quality
  - Weather
  - Inflow/lake levels
  - Geology
  - Etc.



NOVA Satellite Episode

- ‘Earth From Space’
  - Great intro to how much we can learn from satellites



Questions?

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